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Public Health Service

RADIOLOGICAL HEALTH DATA AND REPORTS

Volume 7, Number 12, December 1966

In August 1959, the President directed the Secretary of Health, Education, and Welfare, to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels such as natural background, radiography, medical and industrial uses of isotopes and X rays, and fallout. The Department delegated this responsibility to the Division of Radiological Health, Public Health Service.

Radiological Health Data and Reports, a monthly publication of the Public Health Service, includes data and reports provided to the Division of Radiological Health by Federal agencies, State health departments, and foreign governmental agencies. Pertinent original data and interpretive manuscripts are invited from investigators. These are subject to review by a Board of Editorial Advisors with representatives from the following Federal agencies:

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SUMMARY OF CESIUM-137 AND STRONTIUM-90 CONCENTRATIONS REPORTED IN CERTAIN ALASKAN POPULATIONS AND FOODSTUFFS 1961–1966

R. P. Chandler and *D. R. Snavely* [1]

Published data on cesium–137 and strontium–90 concentrations in certain Alaskan populations and foodstuffs, along with food consumption data, are reviewed and summarized. Where possible, concentrations in the diet and those found in people are compared to FRC guidelines. The seasonal and yearly trends of cesium–137 and strontium–90 concentrations in the diet of Alaskan populations and in people are discussed.

Considerable attention has been directed to assessing the levels and fate of radionuclides in arctic ecosystems. Because of specific dietary habits and unique ecologic situations, the levels of cesium–137 in inhabitants of arctic regions are among the highest documented. In 1960 and 1961, investigators in Norway and Sweden reported relatively high body burdens of cesium–137 in human beings, especially in residents of areas above the Arctic Circle (*1,2*). Surveys of cesium–137 body burdens carried out in 1962 for selected Alaskan residents showed body burdens similar to those found in Norway and Sweden, particularly among persons eating large quantities of caribou meat (*3*). Comparable or higher levels were subsequently found in reindeer herders in northern Finland (*4*), northern U.S.S.R. (*5*), and northern Canada (*6*).

Until 1962, studies of radionuclides in the Alaskan food chain were addressed mainly to questions associated with the proposed Project Chariot site located near Ogotoruk Creek in northwestern Alaska (*7*). Since that time, surveillance activities have continued and expanded in Alaska. The Battelle-Northwest Laboratory has studied the body burdens of cesium–137 in northern Alaskan residents (especially Anaktuvuk Pass) since the summer 1962, at which time levels were found similar to those in Norway and Sweden. The Public Health Service in April and May 1965 expanded the geographic area investigated by measuring cesium–137 body burdens throughout Alaska (*8*).

This paper summarizes selected data since 1961 relative to intake and body burdens of cesium–137 and strontium–90 in Alaskan populations. Comparison with appropriate radiation protection guidance is made where possible.

Radionuclides in foods consumed by Alaskans

The actual or potential body burdens of a specific radionuclide for a population group may be estimated from the radionuclide intake for that population group. To estimate the radionuclide intake by the population group,

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consumption data and the radionuclide concentration in food items consumed must be determined. Since consumption and the radionuclide concentration of specific food items may vary with location and season, and from year to year, it is important to estimate the magnitude of these variations along with average consumption and concentration values. This section summarizes data on the concentration of cesium–137 and strontium–90 found in certain indigenous Alaskan foods and in the total diet of certain Alaskan population groups. Where possible, seasonal, yearly, and location trends are shown for the various food items and/or total diet.

Caribou and reindeer

Although no well-defined range can be given for Alaskan caribou herds, the general grazing areas of the major caribou and reindeer herds, as well as the approximate number of animals in each herd, are shown in figure 1 (*9*).

Average cesium–137 and strontium–90 concentrations in caribou and reindeer muscle samples obtained by the Division of Radiological Health are listed in table 1, along with the minimum and maximum cesium–137 concentrations during the collection period. The codes in parentheses after the herd names correspond to those in figure 1. Comparison of the average cesium–137 concentrations in the caribou and reindeer muscle samples collected during December 1964 and November and December 1965 is made in figure 2. The ratio of maximum to minimum cesium–137 concentrations in muscle samples from the same herd was as large as six. These variations in cesium–137 concentrations in muscle sample taken from animals of the same herd seem to be much greater than the variations of average concentrations in muscle sample taken from animals of different herds. However, average concentrations in the Arctic herd were consistently lower and for the Teller herd consistently

Figure 1. Map of Alaska showing location of the major caribou and reindeer herds and showing whole-body counting locations (*9*)

Table 1. Average radionuclide concentration in caribou and reindeer muscle [a]

Sampling dates	Number of samples	Concentrations in pCi/kg wet weight				
		Average strontium-89	Average strontium-90	Cesium-137		
				Average	Minimum	Maximum
Caribou						
Arctic herd (C-1)						
December 63	3	[b] <5	[b] 17	4,860	3,750	5,680
May 64	5	[b] <5	[b] 400	13,800	5,000	21,000
August 64	5	[b] <5	[b] 40	700	400	1,000
October 64	5	[b] <5	[b] 19	6,880	5,200	11,000
December 64	5	[b] <5	[b] 19	3,900	1,400	5,300
April 65	5	[b] <5	[b] 22	9,600	6,300	14,000
September 65	5	[b] <5	[b] 11	7,720	4,000	12,000
November 65	5	[b] <5	[b] 1	6,220	4,300	7,400
March 66	5	[b] <5	[b] 26	18,400	16,000	22,000
Nelchina herd (C-2)						
November 63	5	[b] 5	[b] 33	21,800	16,900	26,400
April 64	5	[b] 10	[b] 54	5,560	2,600	10,000
August 64	1	<5	31	14,300		
October 64	9	[b] 5	[b] 20	4,220	650	6,200
December 64	5	[b] <5	[b] 30	14,000	7,900	22,000
March 65	5	[b] <5	[b] 48	27,600	16,000	39,000
July 65	5	[b] <5	[b] 7	4,000	1,600	7,300
September 65	5	[b] <5	[b] 26	8,160	5,900	10,000
December 65	5	[b] <5	[b] 33	17,200	16,000	22,000
Peninsula herd (C-3)						
December 63	5	[b] 10	[b] 84	44,800	33,600	57,700
April 64	5	[b] <5	[b] 14	14,800	12,000	18,000
July 64	4	[b] <5	[b] 5	1,680	1,400	2,000
September 64	5	[b] <5	[b] 11	4,630	1,200	9,250
December 64	5	[b] <5	31	18,000	8,700	31,000
August 65	5	[b] <5	[b] 4	2,000	820	3,200
September 65	5	[b] <5	[b] 15	18,000	11,000	32,000
November 65	5	[b] <5	[b] 7	20,100	12,400	25,000
March 66	5	[b] <5	[b] 18	43,800	41,000	46,000
Reindeer						
Kotzebue herd (R-1)						
December 63	4	[b] <5	[b] 31	7,190	6,730	7,540
September 64	5	[b] <5	[b] 74	3,340	2,300	4,900
December 64	4	[b] <5	[b] 268	23,000	13,000	30,000
Selawik herd (R-2)						
December 64	1	<5	578	[c] 34,000		
Buckland and Candle herd (R-3)						
September 64	2	[b] <5	[b] 68	19,600	13,400	25,800
December 64	4	[b] <5	[b] 64	14,000	5,100	32,000
Shismaref herd (R-4)						
September 64	3	[b] <5	[b] 38	8,490	7,660	10,100
December 64	5	[b] <5	[b] 68	12,000	4,900	29,000
March 65	5	[b] <5	[b] 25	18,000	13,000	24,000
September 65	5	[b] <5	[b] 14	6,000	4,000	8,100
November 65	5	[b] <5	[b] 25	16,800	14,000	22,000
February 66	5	[b] <5	[b] 55	18,600	15,000	23,000
Teller herd (R-5)						
December 64	5	[b] <5	[b] 66	35,000	25,000	47,000
November 65	5	[b] <5	[b] 90	27,000	23,000	35,000
June 66	5	[d] —	—	19,000	17,000	21,000
Golovin herd (R-6)						
December 64	5	[b] <5	[b] 96	19,000	11,000	30,000
Stebbins herd (R-7)						
December 64	5	[b] <5	[b] 86	30,000	14,000	37,000
Nunivak Island herd (R-8)						
September 64	5	[b] <5	[b] 75	7,050	5,000	9,200
December 64	5	[b] <5	[b] 128	25,000	9,800	35,000
April 65	5	[b] <5	[b] 28	31,200	27,000	34,000
August 65	35	—	—	7,700	4,000	15,000
January 66	5	[b] <5	[b] 90	27,200	25,000	31,000
April 66	5	[b] <5	[b] 21	33,400	32,000	34,000
St. Paul Island herd (R-9)						
September 64	4	[b] <5	[b] 10	4,860	2,080	7,530
November 64	5	—	—	13,000	4,400	16,000
Nome herd (R-10)						
June 66	5	—	—	22,000	17,000	27,000
Deering herd (R-13)						
December 64	5	[b] <5	[b] 127	28,000	23,000	34,000

[a] Data reported by USPHS in table 1, reference (*11*). Includes recent additions and corrections.
[b] Indicates samples composited before analysis.
[c] Only one sample collected.
[d] Dash indicates no analysis.

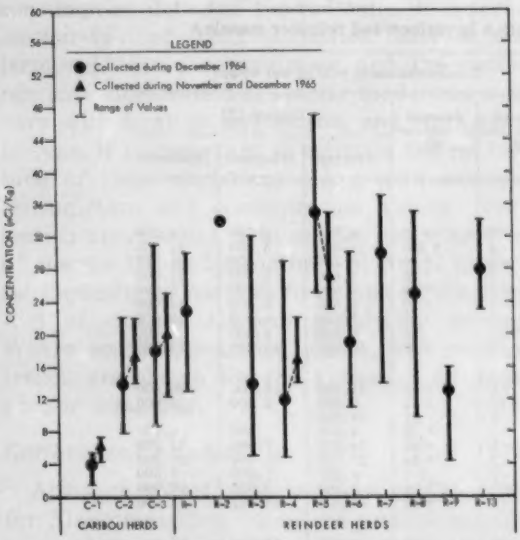

Figure 2. Comparison between average cesium–137 concentrations in Alaskan caribou and reindeer muscle samples collected during December 1964 and during November and December 1965. Values are from table 1.

higher than concentrations in other herds during both periods.

Hanson (*12*) has reported differences in cesium–137 concentrations in caribou flesh samples collected from various areas within the range of the Arctic caribou herd. Concentrations found in caribou flesh samples taken at different locations during the summer are listed in table 2.

Seasonal variations of cesium–137 concentrations in muscle samples were observed in the three caribou herds and two reindeer herds sampled, as shown in figure 3. For the arctic herd, data from both the USPHS Laboratory and the Battelle Pacific Northwest Laboratory are presented. Although the trends are the same, average values reported by the two laboratories vary by a factor of 3 to 6 for those samples collected the same month. On split samples (taken from the same animals) analyzed by the USPHS and the Battelle Pacific Northwest Laboratory, the same difference has been observed. Attempts are being made to explain this difference, but so far no satisfactory explanation has been found. Average concentrations in winter samples were from 3 to 25 times higher than those collected in summer, with peak concentrations in those samples collected near the end of winter and the lowest concentrations in those collected near the end of summer. Not enough samples for the other herds were obtained throughout the year to observe a seasonal variation. Except for the arctic herd, the strontium–90 concentration in muscle samples followed the same seasonal variations as cesium–137, as shown in figure 3. The strontium–90 concentrations in muscle samples from the arctic herd appear to follow no definite pattern.

Table 2. Concentration of cesium-137 in caribou flesh at various locations in northern Alaska during summer period 1960–1964 [a]

Location	Cesium-137 (pCi/g dry weight)				
	1960	1961	1962	1963	1964
Anaktuvuk Pass	------	3.8	12	16	17
Cape Thompson	2.5	5.0	8.1	16	------
Noatak-Kobuk Rivers	7.7	40	------	13	360
Fort Yukon-Arctic Village	------	------	21	51	150

[a] Data reported by Hanson in table 1 (*12*)

The ratios of average cesium–137 concentrations to average strontium–90 concentrations for each sampling of each herd are plotted with time in figure 4. The average ratio of cesium–137/strontium–90 for the five herds is 750, as compared to 800 reported by Hanson for caribou flesh samples collected in northwestern Alaska (*12*).

For comparison purposes, average cesium–137 and strontium–90 concentrations in muscle samples collected during specific time periods each year are presented in table 3. Data given for May and June are from Battelle-Northwest; data given for November and December are from the USPHS. The concentrations in caribou muscle samples from the arctic herd collected during May and June of 1962, 1963, and 1964 show a definite yearly increase, approximately doubling each year.

Yearly trends are not apparent from comparison of cesium–137 concentrations in muscle samples obtained from the three caribou herds during the November to December periods of 1963, 1964, and 1965 nor in samples obtained from two reindeer herds during the November to December periods of 1964 and 1965. February or March would probably be a better period for comparison, since the animals would have had a longer period to reach equilibrium with their

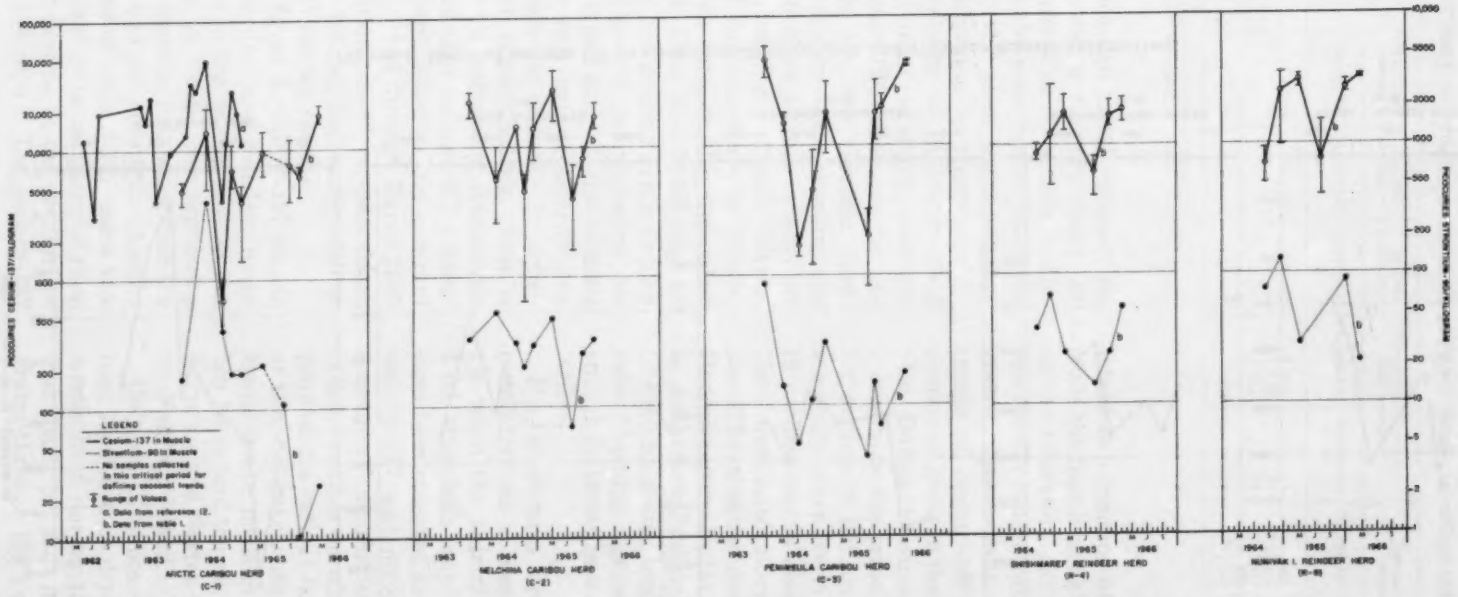

Figure 3. Seasonal trends of cesium–137 and strontium–90 concentrations in Alaskan caribou and reindeer muscle

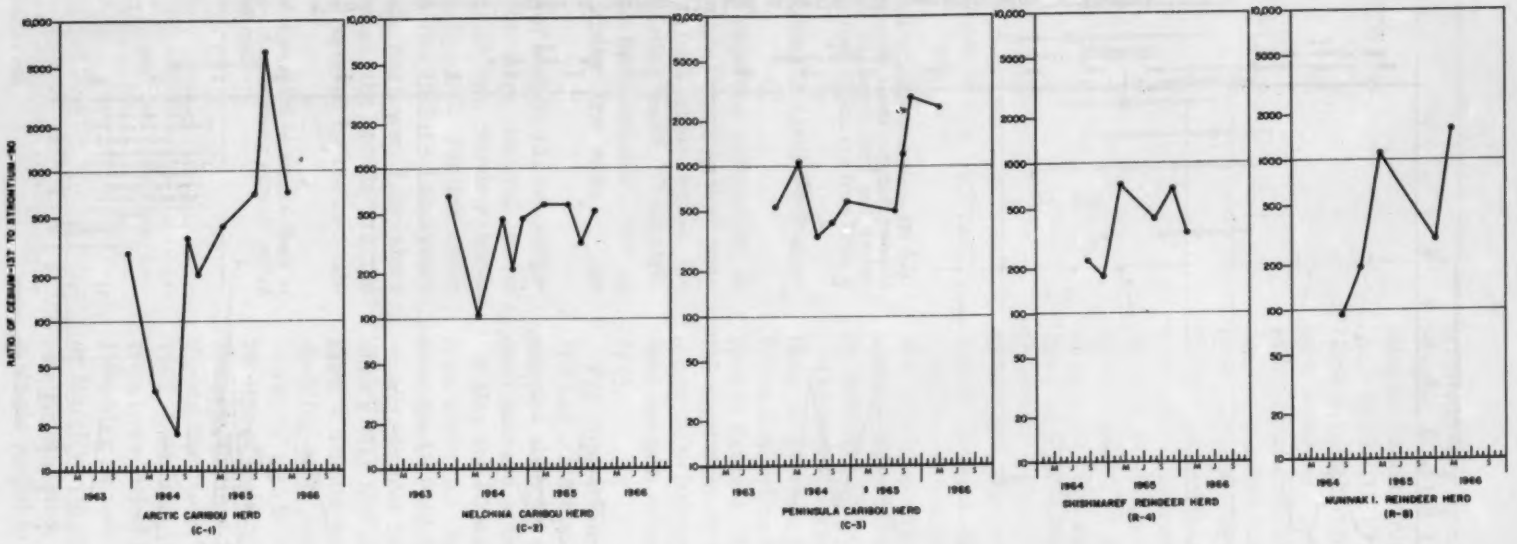

Figure 4. Ratio of cesium–137 to strontium–90 in caribou and reindeer muscle versus time

Table 3. Cesium-137 and strontium-90 concentrations, pCi/g wet weight, in caribou and reindeer muscle samples

Herd	May 1962 average [a]	June 1963 average [a]	May 1964 average [a]	November-December 1963 average [b]		December 1964 average [b]		November-December 1965 average [b]	
	Cesium-137	Cesium-137	Cesium-137	Cesium-137	Strontium-90	Cesium-137	Strontium-90	Cesium-137	Strontium-90
Arctic caribou (C-1)	12,000	25,000	48,000	4,860	17	3,900	19	6,220	1
Nelchina caribou (C-2)	—	—	—	21,800	33	14,000	30	17,200	33
Peninsula caribou (C-3)	—	—	—	44,800	84	18,000	31	20,100	7
Shismaref reindeer (R-4)	—	—	—	—	—	12,000	68	16,800	25
Teller reindeer (R-5)	—	—	—	—	—	35,000	66	27,000	90

[a] Abstracted from figure 3 (Battelle-Northwest data.)
[b] Abstracted from table 1 (USPHS data).

winter diet of lichens and moss; however, no samples were collected during February or March for all 3 years. The November to December 1964 cesium–137 averages for the three caribou herds were less than the November to December 1963 averages by approximately one half. The November to December 1965 cesium–137 averages increased slightly over the November to December 1964 averages for the three caribou herds and one reindeer herd. This suggests that cesium–137 concentrations in lichen and mosses have started to level off in 1964 and may be nearing a plateau. Variations in cesium–137 concentrations in muscle, taken from the same herd during November and December 1963, 1964, and 1965, may be due to variations in the grazing areas (which would vary in cesium–137 concentration depending on plant type, etc., of the animals from year to year and not necessarily due to any large increase or decrease in lichen or moss cesium–137 concentrations. This is supported by Hanson's findings at Anaktuvuk Pass where he found that cesium–137 concentrations in lichens maintained nearly constant values from January 1964 through March 1965 (*12*). Trends of strontium–90 concentrations in muscle samples did not necessarily follow trends in cesium–137 concentrations.

From the data in figure 3, cesium–137 muscle concentrations of caribou and reindeer never reached equilibrium in the winter months but started to increase in September continuing through the winter months, indicating that the cesium–137 intake was not constant. (Assuming a constant intake of cesium–137 and a biological half-life of 30 days in caribou and reindeer (*13*), about 90 percent of the equilibrium value is reached in 100 days.) The cesium–137 intake is a function of many factors which include the food available, which in turn depends on the migratory pattern of the herd, and the cesium–137 concentration in the different plants grazed. Consequently, for predicting long-range trends of cesium–137 in caribou, the rate of change of levels in their food may be more suitable. During the winter months, lichen has been shown to be the principal source of cesium–137 for caribou in the Arctic regions (*5,13*). Consequently, when levels in lichen decrease, levels in caribou should also decrease. The Battelle-Northwest Laboratory has been studying cesium–137 concentrations in lichen since 1959, and Hanson reported (*14*) that measurements made at Anaktuvuk Pass during the first few months of 1965 suggested that the period of maximum rate of buildup was past, but that there was not enough information to accurately predict future levels.

For short-term predictions of cesium–137 concentrations in man, it is important to sample when the animals are actually killed for food, since both seasonal and yearly variations have been observed in the caribou and reindeer cesium–137 and strontium–90 muscle sample concentrations. Although detailed information is not available on which villages or people depend on the various herds for food and the time or times of year when they hunt, general statements can be made in regard to the three caribou herds and the reindeer herds located in the Kotzebue and Norton Sound areas and the herd on Nunivak Island.

Only the Eskimos at Anaktuvuk Pass have been identified as depending on meat from the Arctic herd during the entire year. The fact that part of the Arctic caribou herd migrates through the Pass to get to their winter

or summer range makes the hunting habits of the residents of Anaktuvuk Pass unique (*10*). Almost all of the animals are obtained during one of two periods of the year: during September and October, when the animals are migrating through the Pass to their winter range and April and May, when the animals are migrating back to their summer range (*10*). The animals taken are used as a continuous meat supply (*14*). No other village is believed to depend on the Arctic caribou herd for food the year round; other villages take from this herd when it is in their area. Since this herd has no definite migratory pattern, it may not pass a village for 2 or 3 years.

On the other hand, only a few animals are believed to be taken from the Nelchina and Peninsula caribou herds by natives. The majority are taken by sports hunters during the hunting season (September through March), with most of the animals obtained in October and November (*10*).

The reindeer are usually slaughtered in the fall. Reindeer from the Kotzebue Sound and the Norton Sound areas are consumed locally, but reindeer meat from the government-owned herd on Nunivak Island is shipped to the lower Kuskokwim River Basin, Anchorage, Fairbanks, Juneau, and Seattle, Washington (*10*).

Moose

Watson *et al.* (*15*) reported cesium–137 concentrations in caribou and moose collected from the same location during the same month. In table 4 a comparison is made between levels found in caribou and those found in moose. Concentrations in caribou samples exceeded those in moose samples collected in the same locations and time periods by a factor of 3 to 50. Results of moose muscle samples collected in Canada indicated that cesium–137 levels were at least an order of magnitude below levels in caribou and reindeer muscle (*6*). Consequently, moose meat presents a much lower potential for cesium–137 intake than caribou or reindeer meat. Reasons given for the lower cesium–137 concentrations in moose muscle are the absence of lichen and possible plant litter in their diet (*15*).

Fish

Analytical results for single samples of freshwater and marine fish collected in Alaska and analyzed by the USPHS are listed in table 5. From these data very little can be said concerning comparison between the radionuclide concentrations in freshwater or marine fish, or any seasonal variations in radionuclide concentrations. However, Watson and Richard (*16*) made a study during the summer of 1962 of the radionuclide concentrations in Alaskan fishes in the vicinity of Cape Thompson. Samples were taken from the Arctic Ocean, Marryatt Lagoon, the Kukpuk and Noatak Rivers, and Kelly and Phalarope Lakes. Cesium–137 was not detected in marine fish. Concentrations were highest in the lake fish, approximately a factor of 10 greater than those in fish from the rivers or lagoon. Kolehmainen *et al.* (*17*)

Table 4. Cesium-137 concentrations in the meat of caribou and moose samples [a]

Collection date	Cesium-137 concentrations, pCi/g dry weight							
	Anaktuvuk Pass		Kobuk-Noatak River		Fort Yukon		Cape Thompson	
	Caribou	Moose	Caribou	Moose	Caribou	Moose	Caribou	Moose
July 63			13(6)	5.3(1)			16(5)	4.4(1)
August 63								
September 63					48(11)	2.2(1)		
October 63	[b] 36(10)	4.7(1)						
March 64			190(4)	5.6(2)				
April 64					150(6)	2.6(3)		

[a] Data reported by Watson *et al.* in table 3 (*15*)
[b] Number in parentheses gives number of animals.

Table 5. Cesium-137 and strontium-90 concentrations in freshwater and ocean fish [a]

Common name	Collection date	Cesium-137 (pCi/kg)	Strontium-90 (pCi/kg)
Freshwater			
Grayling	8/15/64	100	31
White fish	12/15/64	15	217
Ocean			
Dog salmon	8/15/64	65	38
Dog salmon	8/15/64	70	38
Dog salmon	8/15/64	470	38

[a] Unpublished USPHS data.

found in Finnish lakes that the cesium–137 concentration in freshwater fish of the same species varied inversely with potassium content of the water.

Milk

Monthly cesium–137 and strontium–90 averages in pasteurized milk for Palmer, Alaska (near Anchorage), are plotted in figure 5 and 6, respectively. For comparison, the Public Health Service's Pasteurized Milk Network national monthly average, maximum, and minimum values are also plotted. The data for the Palmer, Alaska, samples are very similar to the network averages. In no case did the cesium–137 concentration in Palmer milk approach the maximum concentration for the network; the strontium–90 concentration approached the maximum in late 1961, during a period when all concentrations were below 20 pCi/liter. It is not surprising that the concentrations of cesium–137 and strontium–90 in Palmer milk are similar to the Pasteurized Milk Network averages, since both fallout levels (*18*).

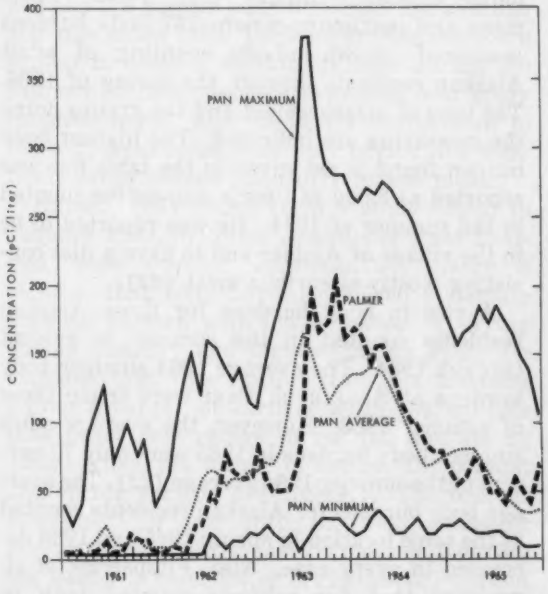

Figure 5. Comparison of the PHS Palmer, Alaska, average monthly concentration of cesium–137 in pasteurized milk to the PHS Pasteurized Milk Network monthly average, maximum, and minimum concentrations (*35*)

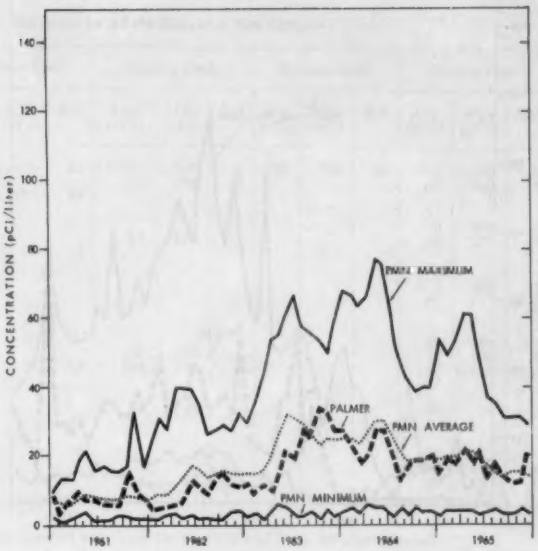

Figure 6. Comparison of the PHS Palmer, Alaska, average monthly concentration of strontium–90 in pasteurized milk to the PHS Pasteurized Milk Network monthly average, maximum, and minimum concentrations (*35*)

Total diet and other foods

Average monthly intakes of strontium–90 and cesium–137 via the total diet since October 1961 from the Public Health Service's Institutional Total Diet Sampling Network station at Palmer, Alaska, are plotted in figures 7 and 8. Designed to estimate the dietary intake of radionuclides by school-age children, the program samples the diets of children at Palmer ranging in age from 6 to 18 years. Details of the program have been described previously (*19*). As observed in figure 7 and 8, the Palmer samples have had the maximum cesium–137 intake for the network in only 4 out of 60 sampling periods; strontium–90 concentrations in Palmer food samples were the peak values of the network in only 3 out of 60 periods. These intake levels are representative mainly of the Matanuska Valley and not of areas where caribou or reindeer consumption is high.

Cesium–137 and strontium–90 concentrations in whale and seal samples taken in Alaska in 1964 and analyzed by the USPHS are listed in table 6. The cesium–137 concentrations are similar to beef samples collected in October 1965 from Chicago, Illinois (*20*).

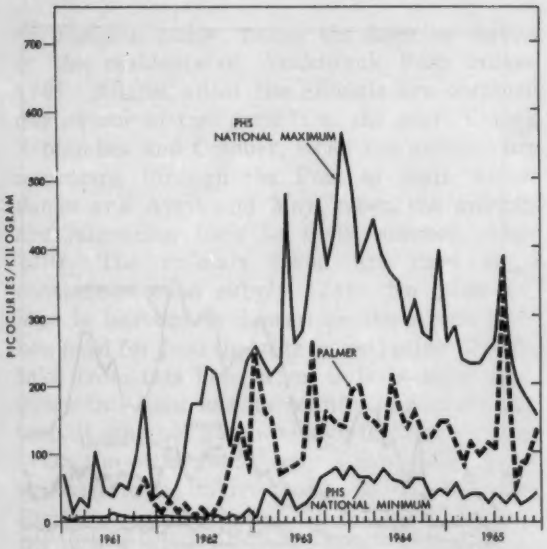

Figure 7. Comparison of the PHS Palmer, Alaska, estimated dietary cesium–137 intake to the estimated maximum and minimum cesium–137 intake through PHS Institutional Total Diet Sampling Network (*36*)

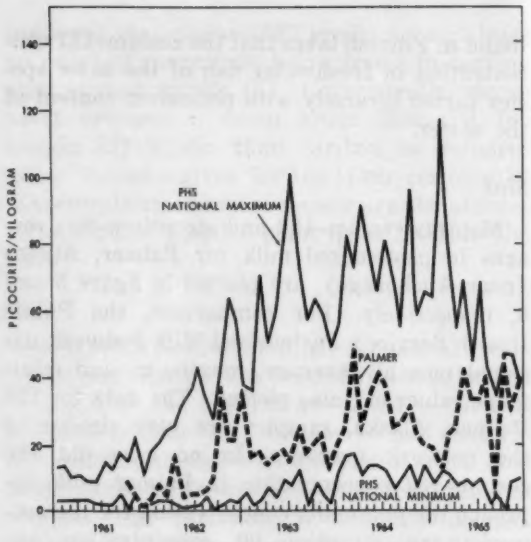

Figure 8. Comparison of the PHS Palmer, Alaska, estimated dietary strontium–90 intake to the estimated maximum and minimum strontium–90 intake through PHS Institutional Total Diet Sampling Network (*36*)

Table 6. Cesium-137 and strontium-90 concentrations in whale and seal muscle [a]

Animal	Collection date	Cesium-137 (pCi/kg)	Strontium-90 (pCi/kg)
Whale	9/15/64	160	16
Whale	10/15/64	110	16
Bearded seal	12/15/64	65	95
Hair seal	12/15/64	15	15

[a] Unpublished USPHS data.

Radionuclide burdens in Alaskan populations

Data for body burdens of radionuclides in human beings in Alaska are fewer than data on concentrations in foods due, in part, to the greater expense and difficulty of measuring human body burdens *in vivo* compared to that of measuring radioactivity in foods, the large land area involved, and the difficulty and expense of collecting appropriate human organs as a result of surgical procedures or post-mortem. Selected data on cesium–137 and strontium–90 body burdens are presented below.

Cesium–137

Battelle-Northwest Laboratories and the Public Health Service have conducted whole-body counting of Alaskan residents. The former used both a shadow shield technique (*21*) and an unshielded sodium iodide crystal technique while the latter used an unshielded sodium iodide crystal technique (*8*). Table 7 lists mean and maximum cesium–137 body burdens measured by whole-body counting of adult Alaskan residents through the spring of 1966. The time of measurement and the groups doing the measuring are indicated. The highest body burden found is not given in the table but was reported as 3,000 nCi for a non-native counted in the summer of 1964. He was reported to be in the village of Ambler and to have a diet consisting mostly of caribou meat (*22*).

A rise in body burdens for those Alaskan residents counted in the summer is evident through 1964. The average 1964 summer body burdens at Anaktuvuk Pass were triple those of summer 1962. However, the average adult summer body burdens in 1965 were only 70 percent of the summer 1964 average (*23*). The average body burdens for Alaskan residents counted at the same location in spring 1965 and 1966 decreased in every case. Also, Fitzpatrick *et al.* reported that for subjects counted both in spring 1965 and 1966, the maximum and average body burdens decreased at each location, with the exception of Kanakanak and Tanana,

Table 7. Mean total cesium-137 body burdens in adult Alaskan residents [a]

Location [b]	Summer 1962			Summer 1963			Summer 1964			Spring 1965			Summer 1965			Spring 1966		
	Avg (nCi)	Max (nCi)	Ref	Avg (nCi)	Max (nCi)	Ref	Avg (nCi)	Max (nCi)	Ref	Avg (nCi)	Max (nCi)	Ref	Avg (nCi)	Max (nCi)	Ref	Avg (nCi)	Max (nCi)	Ref
Anaktuvuk Pass	421	790	22	628	1,240	22	1,280	2,400	22	[c]1,052	1,368	8	920	1,740	24	680	1,040	24
Anchorage										70	206	8				60	850	24
Arctic Village							614	1,156	22									
Barrow	52	166	22	60	177	22										160	440	24
Bethel										93	293	8				40	200	24
Coastal Villages [c]	100		12				130		12									
Egegik																250	830	24
Fairbanks																20	190	24
Fort Yukon				34	181	22												
Juneau																10	<40	24
Kanakanak										178	1,279	8				120	1,100	24
Kotzebue	138	518	22	140	732	22	321	929	22	454	979	8				240	1,390	24
Little Diomede	22	35	22															
Mt. Edgecombe										43	138	8				20	70	24
Point Hope	17	119	22	39	88	22	50	92	22									
River Villages [d]	150		12	150			360		12									
Selawik																1,250	2,400	24
Tanana										44	88	8				30	160	24

[a] For USPHS data, males only were counted.
[b] For USPHS data, the location represents the counting location. Persons counted were from the location and from outlying villages.
[c] Kivalina, Deering, Elim.
[d] Noatak, Selawik, Noorvik, Kiana, Shungnak, Kobuk, Ambler.
[e] Based on measurements of three people eating large amounts of caribou.

where slightly higher maximums and minimums were observed (*24*). Forty-nine subjects were counted both years, and the average decreased from 280 nCi in 1965 to 140 nCi in 1966. Of the new counting locations added in 1966, Selawik had the highest body burdens. The average and maximum body burdens at Selawik were similar to those at Anaktuvuk Pass during the summer of 1964. Selawik is located near many reindeer herds, and the levels comparable to those at Anaktuvuk Pass may be due to a relatively large consumption of reindeer meat.

Hanson (*25*) found from a study begun in January 1964, in which Anaktuvuk Pass Eskimos were counted approximately every 2 months, that body burdens showed a definite seasonal pattern with lowest values occurring during January and highest during July. He explains that this results from the Eskimos killing a supply of caribou when the animals pass near their village in the fall and spring (fall caribou are lowest in cesium–137 content and spring caribou are highest). The meat is stockpiled for use until the next slaughter period. Consequently, caribou meat used during the winter is much lower in cesium–137 content than that used during the late spring and summer months. The winter meat supply is supplemented by fresh meat obtained from animals found within a few miles of the village. The cesium–137 content of these animals increases as the winter progresses. Hanson (*25*) also reports that cesium–137 body burdens were highest for men and lowest for children in the Anaktuvuk Pass studies. However, there appeared to be no difference between males and females up to age 20. Maximum body burdens were observed for persons between 40 and 60 years of age.

Strontium–90

The skeleton is the critical organ for ingestion of strontium–90 (*26*). Limited numbers of bone samples from Alaska have been obtained through the Public Health Service Human Bone Network (*27–30*). Samples were obtained from surgical procedures at two PHS Alaska Health Service hospitals, which treat patients from surrounding areas (figure 1). At the present time, strontium–90 concentrations in only a few samples have been reported.

Table 8 lists results of analyses by age at time of surgery, type of bone, place and date of surgical procedure, and pCi strontium–90/g calcium for samples collected at the two hospitals during 1964 and 1965. Figure 9 indicates individual Alaskan bone samples compared with the average and range for all the samples col-

Table 8. Strontium-90 in individual rib samples [a]

Age of obtained specimen	Place of obtained specimen	Date of procurement	Strontium-90 (pCi/g Ca)
2	Mt. Edgecumbe	6/64	3.23
12	Anchorage	5/65	3.13
17	Anchorage	4/65	4.31
17	Anchorage	3/65	4.71
20	Anchorage	9/64	2.62
22	Anchorage	3/65	1.28
23	Mt. Edgecumbe	4/64	0.62
23	Anchorage	10/64	3.91
25	Anchorage	4/65	1.17
Average			2.78

[a] Data from references (*27–30*) and USPHS basic data files

lected in the United States during 1964 and first quarter 1965.

The Alaskan samples were rib bones and the levels were similar to the U.S. yearly and quarterly averages for all bones (the majority were vertebrae) in the network. Kulp *et al.* (*31*) reported the ratio of strontium–90 concentrations in individual bones to concentrations in the whole skeleton as 2.1 for vertebrae, 1.4 for ribs, 0.45 for long-bone shaft. Skeletons were from adult individuals who died in 1958 and 1959 in New York. Although it would be better to compare the Alaskan samples with the U.S. average for rib bones only, most of the Alaskan samples are still in the range of the U.S. average when multipled by 1.5 (2.1 vertebrae/1.4 rib).

Dietary studies in Alaska

A dietary survey made by the Arctic Health Research Center (*32*) on Alaskan Eskimo and Indian diets has shown an extreme variation in individual mean daily intake of 11 major nutrients. They also found that the use of imported foods was limited in the villages and that the supply of local foods fluctuated from season to season and year to year. Use of different meat and fish products varied considerably in the 11 villages studied. The average estimated daily intake of meat or fish for an individual in a native village in the northern coastal areas was 1.5 lbs. (0.68 kg), and on occasion an individual might consume as much as 5.5 to 6 lbs (2.5 to 2.7 kg).

Hanson and Palmer report the estimated weekly consumption of caribou meat by the natives of Anaktuvuk Pass as 5 to 6 kg fresh weight with the exception of late 1963 (*14*). This would amount to an average daily intake of caribou meat of approximately 0.8 kg.

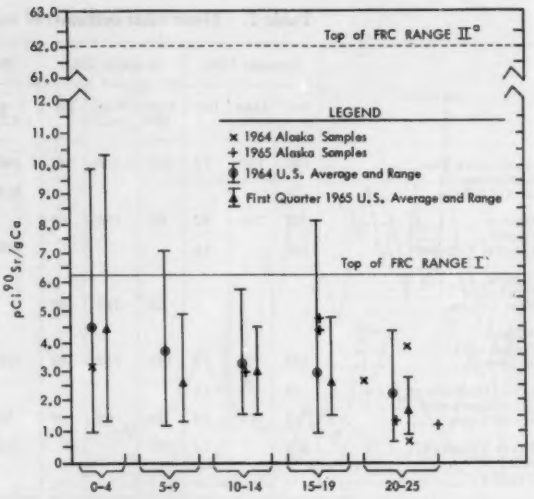

Figure 9. Strontium–90 in Alaskan bone samples as compared to other U.S. bone samples

[a] Calculation based on the upper value of FRC range II, which corresponds to a dose for continuous intake at that level equal to one-ninth of the RPG for the individual, and the FRC assumption that 1 nanocurie of strontium–90 per gram calcium in the bone gives a dose to the bone marrow of 0.9 rad in 1 year (*26, 34*)

Hanson and Palmer (*33*), in conducting their whole-body counting measurement in northern Alaska in 1962 and 1963, also obtained dietary information. For study purposes they chose villages which depended heavily, and other villages which depended less, on caribou meat (river and coastal villages). Also studied was a native village at Fort Yukon which used moose as a major food source during the fall and winter months. Of the natives studied at the six locations—Anaktuvuk Pass, river villages (villages on the Noatak and Kobuk Rivers), Barrow, Kotzebue, Point Hope, and Fort Yukon—it was found that native animals contributed about 40 to 70 percent of the total diet by weight. They found caribou to be most important in the diet of natives at Anaktuvuk Pass and least important at Fort Yukon. The highest consumption of reindeer meat was by Barrow and Kotzebue residents, to supplement caribou. Moose meat was found to be most important in the Fort Yukon diets. Walrus (*Odobenus rosmarus*), ringed seal (*Phoca* [*Pusa*] *hispida*), and the bearded seal or ugruk (*Erignathus*

barbatus) were the most important marine mammals taken by all Eskimos.

Hanson and Palmer (*33*) also point out that a variety of fish and birds are utilized depending upon the village and season. Fish include arctic char (*Salvelinus alpinus*), grayling (*Thymallus articus*), tomcods (*Boreogadus saida*), whitefish (*Coregonus spp.*), and salmon (*Oncorhynchus spp.*). Birds include eiders, murres, and auklets for coastal Eskimos; and ducks and ptarmigan for river village Eskimos. Greatest use of imported foods was found in villages which employed natives in a local industry. The wages allowed them to buy more food and the work restricted their hunting activities.

Levels with respect to diet and Federal Radiation Council Guidelines

In FRC Report No. 7, Section 4.9 (*34*), the Federal Radiation Council gives guidance on the Alaskan situation. Since cesium–137 is distributed throughout the body, recommendations for whole-body exposure apply. The appropriate Radiation Protection Guides are 0.5 rem/year for individuals in the general population when measured directly or an average of 0.17 rem/year to a suitable sample of a population group, when direct measurement is not made. The FRC further states that "an annual average body burden in adults of 3,000 nanocuries and 1,000 nanocuries would be estimated to result in these respective doses." Of the maximum values for the various locations given in table 7, all were below the FRC guidance of 3,000 nanocuries. The highest was 80 percent of the guidance. The maximum body burden for an Alaskan resident as reported previously was 3,000 nanocuries (the FRC Radiation Protection Guides for an individual). He was counted during the summer of 1964 and was reported to consume unusually large amounts of caribou meat. The average body burdens in table 7 were above 1,000 nanocuries at Anaktuvuk Pass for the summer of 1964 and at Selawik for the spring of 1966. However, in both of these cases the maximum burdens were less than a factor of 3 of the average indicating that the individuals measured in the locality were not exceeding the individual RPG.

Relation of dietary information to cesium–137 body burdens indicated that there was a direct correlation between cesium–137 body burdens and caribou consumption (*8,24,33*) and that caribou is the major source of dietary cesium–137 intake for those groups with elevated levels. Lower amounts of cesium–137 were found for natives who ate appreciable amounts of fish, marine mammals, or processed food (*25*). The maximum cesium–137 value for caribou in figure 3 was that reported by Hanson in May 1964 of 48,000 pCi/kg fresh weight. The lowest average value in figure 3 reported by PHS was 700 pCi/kg collected in July 1964. If a daily intake of caribou meat of 0.8 kg is assumed and cesium–137 in the diet is in equilibrium with that in the people consuming the meat, the above values would correspond to cesium–137 body burdens of 5,530 and 81 nCi, respectively (biological half-life of 100 days assumed). However, the body burden will reach only 90 percent of equilibrium conditions, from the start of intake of contaminated meat at a given cesium–137 level, in about 330 days. It has been shown that cesium–137 levels in caribou meat vary considerably with season. Consequently, levels in individuals consuming caribou or reindeer meat would highly depend on the time of year the meat they consumed was obtained. There is no evidence that any group of people who live on caribou or reindeer meat the year round kill animals only in late winter or early spring. In fact, evidence is to the contrary; most of the reindeer are slaughtered in the fall. Measured cesium–137 body burdens support this fact as none have approached the 5,530 nCi figure. All other food samples reviewed in this paper are orders of magnitude below caribou or reindeer muscle in cesium–137 concentration, although for some items only two or three samples were reported.

Using the factor of 1 nCi strontium–90/g calcium in the bone as yielding a dose to the bone marrow of 0.9 rad in 1 year (*34*) and assuming linear proportionality, a value of 556 pCi strontium–90/g calcium in bone would yield the numerical value of the individual RPG (0.5 rad) in 1 year. The highest strontium–90 level in the few Alaskan bone samples analyzed was 7.95 pCi/g calcium or about 1 percent of the RPG. More data are needed to characterize

more fully the body burdens of this nuclide in the Alaskan population. Especially needed are bone samples from those ethnic groups which consume relatively large amounts of caribou or fish, or whose diet is not the typical western diet.

The highest concentration of strontium–90 in Alaskan foods summarized in the article was 578 pCi/kg reported for a sample collected in December 1964 from the Selawik reindeer herd. If a daily consumption of 0.8 kg of reindeer meat is assumed, consumption of meat contaminated to this level would result in a strontium–90 daily intake of 460 pCi/kg, approximately twice the day value of FRC range II for strontium–90 (*26*) of 200 pCi/day. However, this guidance is for continual intake at this level; and concentrations reported for caribou and reindeer samples collected before and since December 1964 have been much lower than the 578 pCi/kg value. Also, a continuous daily intake of strontium–90 at the upper limit of FRC range II results in an estimated bone marrow dose rate of only one-third the RPG for the average of a suitable sample of an exposed population group (0.17 rem/year) (*26*).

Summary

Data have been reviewed and summarized for cesium–137 and strontium–90 concentrations in certain Alaskan populations and foodstuffs. The highest cesium–137 body burden reported in Alaska was during the summer of 1964 and equal to the FRC Radiation Protection Guides of 3,000 nCi. The burden was found in a non-native who was reported to have a diet consisting mostly of caribou meat. The average Alaskan body burdens reviewed in this report increased through the summer of 1964 but since have decreased through the spring of 1966 when body burdens from the same location and season of the year were compared. Average body burdens were all below the RPG for a suitable sample of a population group except for two locations. However, at these locations all individual body burdens measured were below the RPG for individuals. Dietary studies indicated that cesium–137 body burdens were directly related to caribou consumption, the major source of cesium–137 for those groups with elevated levels. There is no evidence that other foods contributed a major amount to the elevated levels. Levels in foodstuffs substantiated this fact with maximum levels in caribou and reindeer flesh orders of magnitude above other foods. There are seasonal variations in caribou and reindeer flesh samples with winter concentrations 3 to 25 times the summer concentrations. However, since December 1963, cesium–137 concentrations in caribou and reindeer show no definite trends upward or downward when comparing the concentrations in samples collected from the same herd and time period each year. This seems consistent, since levels in lichens at Anaktuvuk Pass were reported nearly constant from January 1964 through March 1965. The variations after January 1964 in the cesium–137 concentrations in samples from the same herd when comparing the same time period each year are probably due to the animals grazing in different areas and the differences in types and amounts of food available each year.

There is little data on strontium–90 concentrations in human bone samples of Alaskan residents. For the few reported, concentrations are similar to the U.S. average. However, the dietary habits of the ethnic groups which these bones represent are not available. The highest strontium–90 concentration in Alaskan foods reviewed in the paper was 578 pCi/kg in reindeer meat collected in December 1964. A daily consumption of 0.8 kg of meat contaminated to this level results in a strontium–90 intake level about twice the upper value of FRC range II.

However, this guidance is for continual intake at this level and concentrations reported for caribou and reindeer samples collected before and since December 1964 have been much lower than the 578 pCi/kg value. Also, a continuous daily intake of strontium–90 at the upper limit of FRC range II results in an estimated bone marrow dose rate of only one-third the RPG for the average of an exposed population group.

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(10) Information on migration and grazing habits of each herd, slaughtering periods, approximate seasons, and consumption of meat was supplied for caribou by Terry McGowan, Caribou Project Leader, and Kenneth Neiland, Parasitologist, Alaska Department of Fish and Game; and for reindeer by David O. Scott, Jr., Range Conservationist of the Bureau of Indian Affairs, U.S. Department of Interior.

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CESIUM-137 BODY BURDENS IN ALASKAN MEN, SPRING 1966

D. E. P. Fitzpatrick, J. L. Russell, O. G. Briscoe, and *C. R. Calvert*[1]

The cesium–137 body burdens of caribou-eating Alaskan men continue to be elevated, although in general the average body burdens are decreasing compared to those observed in 1965. Elevated cesium–137 body burdens are well correlated with caribou (reindeer) consumption, and non-caribou eaters exhibit cesium–137 body burdens similar to residents in the conterminous United States. During the 1966 study, the cesium–137 body burden of a total of 418 Alaskan men was obtained. The body burdens observed ranged from 2,400 to less than 40 nCi and indicated a wide range of values depending on location.

During the past few years several investigators have reported relatively high cesium–137 body burdens in inhabitants of Arctic and subarctic regions, as a result of the deposition of fallout from atmospheric nuclear testing (*1-10*). Cesium–137 has a relatively high yield in nuclear fission and an appreciably long half-life, and behaves much like potassium physiologically. The relatively high body burdens observed in people in northern latitudes (above approximately 56°N) result from a particular ecological chain: lichen to caribou (reindeer) to man. Since cesium–137 is currently one of the principal radionuclides in air and lichen acts as an accumulator of cesium–137, it is likely that the body burdens will continue to be relatively high in Alaskans whose diet includes a substantial amount of caribou meat.

The Division of Radiological Health, Public Health Service, is conducting a continuing surveillance program to determine radioactivity levels in Alaska and to evaluate the health implications.

In addition to a routine program of surveillance of milk, food, and air particulates for radioactivity, cesium–137 body burdens were measured in Alaskans during the spring of 1965 (*11,12*). During April and May 1966, a surveillance team was again sent to Alaska to measure directly the cesium–137 body burdens of the inhabitants. This is a report of the body burdens of Alaskan men observed in the spring of 1966, and a description of the method used.

Selection of counting locations and subjects

To provide geographic coverage of the State, seven PHS Indian Health hospitals, located at Mount Edgecumbe, Anchorage, Kanakanak, Bethel, Kotzebue, Barrow, and Tanana, were selected as counting locations. The Indian Health hospitals served as excellent operating bases because of the availability of subjects, contact with health aides in surrounding villages, and arrangements for local transportation. In addition, counting operations were con-

[1] The authors are members of the Division of Radiological Health, U.S. Public Health Service. Dr. Fitzpatrick is a member of the research team assigned to the Northeastern Radiological Health Laboratory, Winchester, Massachusetts; Mr. Russell and Mr. Briscoe are assigned to the Technical Development Group, Rockville, Maryland; and Mrs. Calvert, project officer for the Alaskan Study, is assigned to Technical Operations Branch, Washington, D.C. Dr. Fitzpatrick, Mr. Russell, and Mr. Briscoe conducted the counting operations in Alaska and are the investigating team.

ducted at the St. Anne's Hospital in Juneau, the Bassett Army Hospital at Fort Wainwright in Fairbanks, and at three small villages: Egegik, Anaktuvuk Pass, and Selawik. Anaktuvuk Pass was chosen to provide an operational comparison with data collected by Dr. Wayne Hanson, Battelle-Northwest Laboratory; Selawik and Egegik were chosen because they are areas of high caribou (reindeer) consumption. Figure 1 shows the locations where subjects were counted.

Only adult men were counted because counting geometries were generally more consistent for men than for women or children, and counting accuracy was therefore improved. With the counting technique used, it was not possible to measure potassium–40 body burdens.

The team attempted to locate and count subjects who had been counted by the Division of Radiological Health team in 1965, in order to obtain data on the change in cesium–137 body burdens of these individuals.

Procedure

The cesium–137 body burden counting technique employed in this study was similar to that described by Palmer *(13)* and also similar to the method used by the Division of Radiological Health team in 1965. A 3- by 3-inch NaI (Tl) integral type, hermetically sealed detector, in a special holder designed to hold the thighs together, was placed in the lap of the subject who then bent over the detector and rested his elbows on his knees. A 10-minute count was taken, using a multichannel pulse height analyzer. The system was calibrated using cesium–137 standard sources suitably attached to bags of sugar as a phantom. Since counting efficiency depends on anthropometric factors, phantoms of various weights were constructed and a counting efficiency curve as a function of body weight was determined according to the method of Palmer *(13)*.

Each member of the investigating team was counted at both the National Institutes of Health and the National Naval Medical Center, to determine his cesium–137 body burden. In order to provide a suitable background count, a member of the team was counted daily at each location and a ratio was calculated between the cesium–137 portion and a "non cesium–137" portion of the spectrum after the cesium–137 contribution of the team member was subtracted. This ratio was used to correct the spectra of the Alaskan men for background. For body burdens greater than 200 nCi of cesium–137, the results are estimated to be accurate within ±20 percent at the 95 percent confidence level. The uncertainty increased at lower body burdens and was about ±100 percent at 40 nCi. Values reported as less than 40 nCi may have uncertainties greater than the value itself. Averages, however, were calculated using the observed values; all counts that were less than background were taken to be zero.

The problem of peak-shift due to varying magnetic fields, observed during the 1960 counting operation, was solved by the use of magnetic shielding around the phototube and phototube base.

Because the counting rates in the potassium–40 spectral region for the subjects were not significantly different from background, potassium–40 body burdens could not be determined. This problem is inherent in the "lap-counting" method, and makes comparison with other data, which are related to cesium-potassium ratios, difficult.

Each individual was interviewed before counting to obtain information on his diet. The dietary information was used to classify the men into five general categories based on the major meat item of the diet. These categories were caribou (reindeer), fish, marine mammals, game animals, and commercial products. Commercial products were largely imported from the conterminous United States.

Comparison of cesium–137 body burdens in 1966 with those in 1965

Of the 180 men counted in 1965, 49 were recounted in 1966. The cesium–137 body burdens of these, as given in table 1, show a general trend of decreasing body burdens. In five of the seven sampling locations, the average cesium–137 body burden had decreased by 25 to 70 percent over the year. No significant change was found in the body burdens at two locations. Attention is directed to the average values for the 49 men which show that the

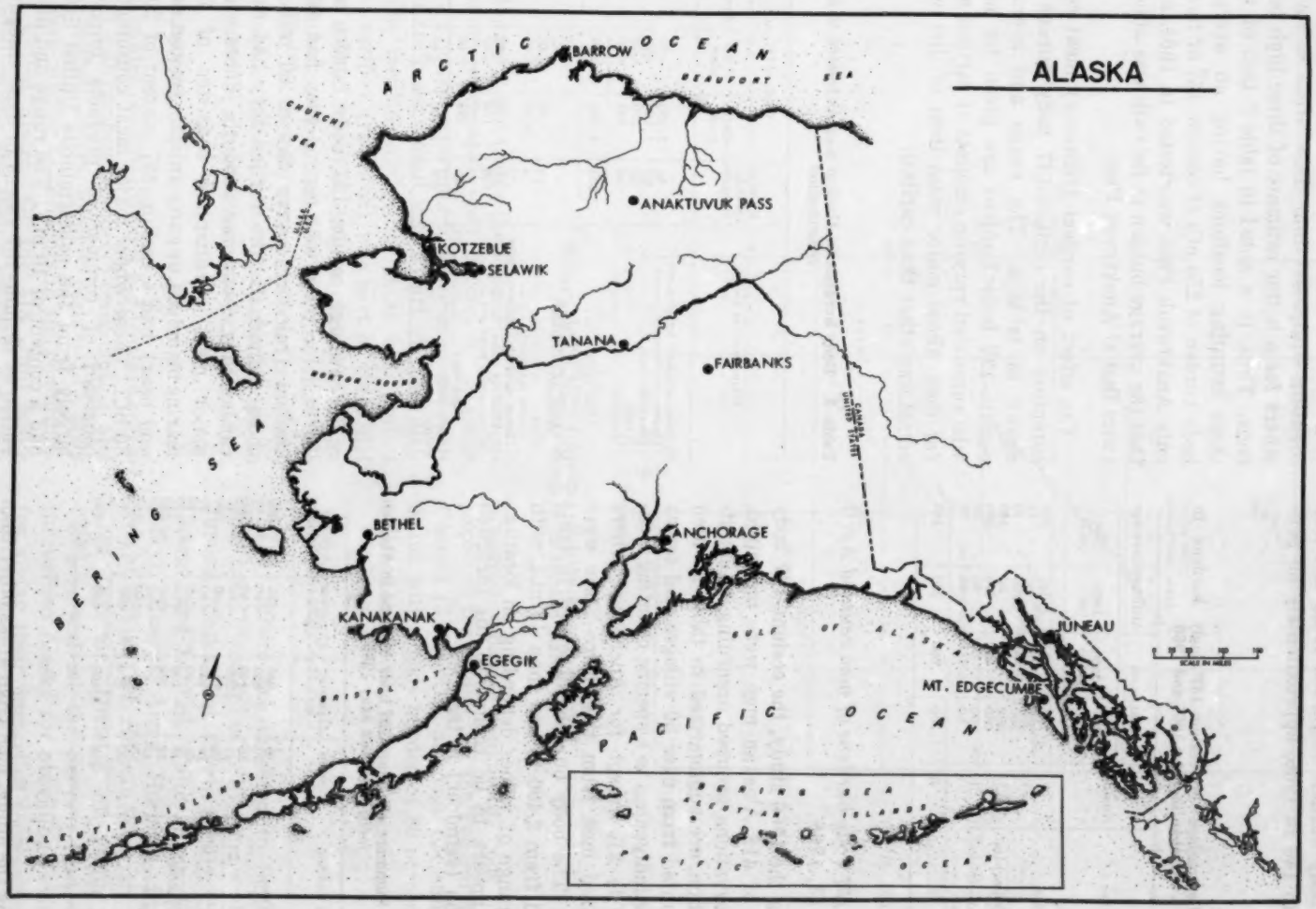

Figure 1. Counting locations for whole body counting surveillance, spring 1966

average body burden decreased from 280 nCi in 1965 to 140 in 1966, approximately 50 percent.

Table 1. Comparison of cesium-137 body burdens in Alaskan men for 1965 and 1966

Location	Number	Maximum		Arithmetic average	
		1965 (nCi)	1966 (nCi)	1965 (nCi)	1966 (nCi)
Anaktuvuk Pass	2	1,300	460	1,040	380
Anchorage	11	200	160	80	40
Bethel	3	290	80	190	50
Kanakanak (Dillingham)	8	260	350	80	100
Kotzebue	5	760	680	470	360
Mt. Edgecumbe (Sitka)	12	90	60	40	30
Tanana	8	80	160	40	40
All locations	49	1,300	680	280	140

Cesium–137 body burdens of men counted April 25–May 18, 1966

During the 1966 study, the cesium–137 body burdens of 418 Alaskan men were measured. The observations grouped according to counting location are summarized in table 2. Men were counted from over 50 villages and towns and were indigenous to a specific counting location (table 2), except for Anchorage where hospitalized men from the entire State were counted. The body burdens observed in table 2 ranged from 2,400 to less than 40 nCi, with a wide range of values depending on location, which appears to be related to the inclusion of caribou (reindeer) in the diet.

Table 2. Summary of cesium-137 body burdens in Alaskan men, April and May 1966

Counting location	Number	Maximum (nCi)	Minimum (nCi)	Average (nCi)
Anaktuvuk Pass	8	1,040	290	680
Anchorage	70	850	<40	60
Barrow	49	440	<40	160
Bethel	44	200	<40	40
Egegik	29	820	<40	250
Fairbanks	29	190	<40	20
Juneau	31	<40	<40	10
Kanakanak (Dillingham)	28	1,100	<40	120
Kotzebue	28	1,390	<40	240
Mt. Edgecumbe (Sitka)	42	70	<40	20
Selawik	30	2,400	180	1,250
Tanana	30	160	<40	30
All locations	418	2,400	<40	180

During the study, men from areas other than those included in the 1965 study showed high body burdens and led to the transfer of the counting equipment into these areas to count others for a better estimate of these high burdens. Thus, it is noted in table 3 that of the three counting locations having an average body burden of 250 nCi of cesium–137 or more, only Anaktuvuk Pass was tested in 1965, and that the average burden at Selawik was almost twice that at Anaktuvuk Pass.

The effect of caribou (reindeer) meat consumption on the cesium–137 body burden is shown in table 3. The range and average cesium–137 body burdens are given for men who consumed varying amounts of caribou and for men whose major meat item of diet was something other than caribou.

Table 3. Body burdens in Alaskan men as related to meat consumption

Major meat in diet	Number of individuals	Cesium-137, nCi		
		Maximum	Minimum	Average
Caribou/reindeer, by frequency:				
Daily	66	2,400	<40	780
Less than daily	93	1,100	<40	190
Weekly	29	270	<40	80
Monthly	35	290	<40	60
Summary	223	2,400	<40	330
Meat items other than caribou/reindeer:				
Fish	12	60	<40	10
Marine mammals	4	<40	<40	20
Game animals (moose, deer, bear, etc.)	41	120	<40	30
Commercial products	138	150	<40	10
Summary	195	150	<40	15
Total	418	2,400	<40	180

The average cesium–137 body burden was 780 nCi for those who replied they had eaten caribou (reindeer) every day to 60 nCi for those individuals who replied they had eaten caribou only about once a month. Those whose major meat consumption consisted of fish, marine mammals, or game animals (moose, deer, and bear) had a cesium–137 content of 20 to 30 nCi. Those whose major meat consumption consisted of commercial products imported largely from the conterminous United States had a content of 10 nCi. The range and distribution of cesium–137 values in most categories suggested a log-normal distribution.

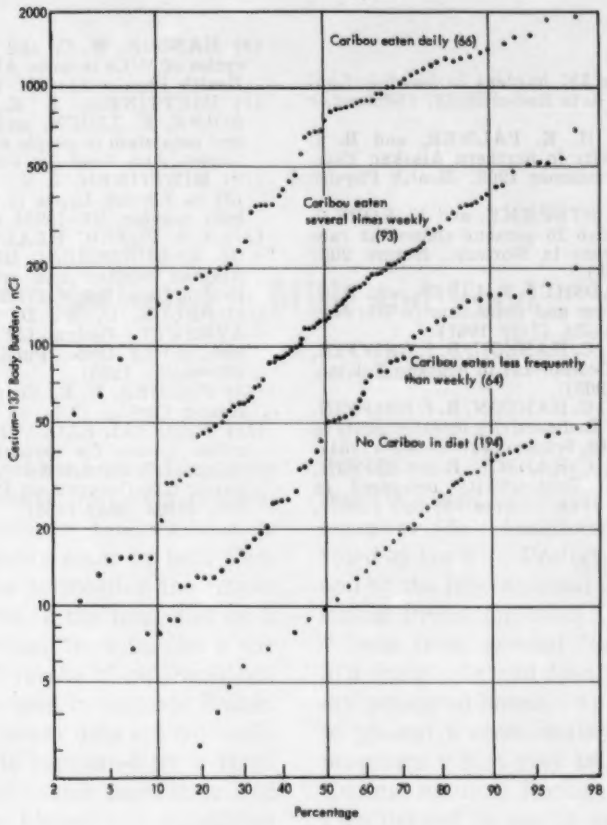

Figure 2. Cumulative frequency distributions of observed cesium–137 body burdens in Alaskan males

Figure 2 illustrates the log-normal distribution of cesium–137 body burden for Alaskan men grouped according to whether or not caribou (reindeer) meat was a part of their diet.

The median burden for those who replied that caribou (reindeer) was part of their diet was 150 nCi cesium–137 as compared to an arithmetic average of 330 nCi, and for those who replied they did not eat caribou (reindeer), the median burden was 10 nCi cesium–137 as compared to an arithmetic average of 15 nCi.

Conclusions

Elevated cesium–137 body burdens are correlated with caribou (reindeer) consumption, and non-caribou eaters exhibit cesium–137 body burdens similar to residents in the conterminous United States. Of the 418 adult males counted during the spring of 1966, none was observed to have a cesium–137 body burden in excess of the guidance of the Federal Radiation Council (3,000 nCi), although one subject was found with a body burden of 80 percent (2,400 nCi) of this level (*14*).

Acknowledgment

The authors are indebted to Sister Mary Angelus, Director of St. Anne's Hospital, Juneau, Alaska; Col. Edwin Lindig, Officer-In-Charge, and Lt. Col. Walter Erne, Executive Officer, Bassett Army Hospital, Ft. Wainwright, Alaska; Dr. Holman Wherritt, Alaskan Area Director, Division of Indian Health, USPHS; and all the Service Unit directors throughout Alaska for providing facilities and for giving their unexcelled cooperation in the conduct of these studies.

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Section I. Milk and Food

In the determination of the internal exposure to man from environmental radiation sources, primary interest centers on radionuclides in the diet. Efforts are being made by both Federal and State agencies to monitor the intake of various radionuclides in the total diet on a continuing basis. Although the total diet is the most direct measure of intake of radionuclides, indicator foods may be used to estimate dietary intake where specific dietary data are not available. As fresh milk is consumed by a large segment of the United States population and contains most of the biologically significant radionuclides from nuclear test debris which appear in the diet, it is the single food item most often used as an indicator of the population's intake of radionuclides. Moreover, it is the major source of dietary intake of short-lived radionuclides. In the absence of specific dietary information, it is possible to approximate the total daily dietary intake of selected radionuclides as being equivalent to the intake represented by the consumption of 1 liter of milk. More direct estimates of dietary intake of radionuclides than those furnished by indicator foods can be obtained by analyses of the total diet or representative principal food items or groups combined with appropriate consumption data.

The Federal Radiation Council (FRC) has developed Radiation Protection Guides (RPG's) for controlling normal peacetime nuclear operations, assuming continuous exposure from intake by the population at large (*1–3*). The RPG's do not and cannot establish a line which is safe on one side and unsafe on the other; they do provide, however, an indication of when there is a need to initiate careful evaluation of exposure (*3*). Additional guidelines are provided by the FRC Protective Action Guides (*4*) and by the International Commission on Radiological Protection (*5,6*).

Data from selected National, International, and State milk and food surveillance activities are presented herein. An effort has been made to present a cross-section of routine sampling programs which may be considered of a continuing nature. Routine milk sampling has been defined as one or more samples collected per month.

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NATIONAL AND INTERNATIONAL MILK SURVEILLANCE

As part of continuing efforts to quantitatively monitor man's exposure to radionuclides, various National and International organizations routinely monitor radionuclide levels in milk.

1. Pasteurized Milk Network August 1966

Division of Radiological Health and *Division of Environmental Engineering and Food Protection, PHS*

The Public Health Service's pasteurized milk surveillance program had its origin in a raw milk monitoring network (*1*) established by the Service in 1957. One of the primary objectives of this network was the development of methods for milk collection and radiochemical analysis suitable for larger scale programs.

Experience derived from this study led to the activation of a pasteurized milk sampling program with stations selected to provide nationwide surveillance of milk production and consumption areas. The present Pasteurized Milk Network (PMN), which consists of 63 stations, has at least one station in every State, the Canal Zone, and Puerto Rico (figure 1).

Sampling procedure

Samples are collected through the cooperation of State and local milk sanitation authorities. According to established procedures, the sample at each station is composited of subsamples

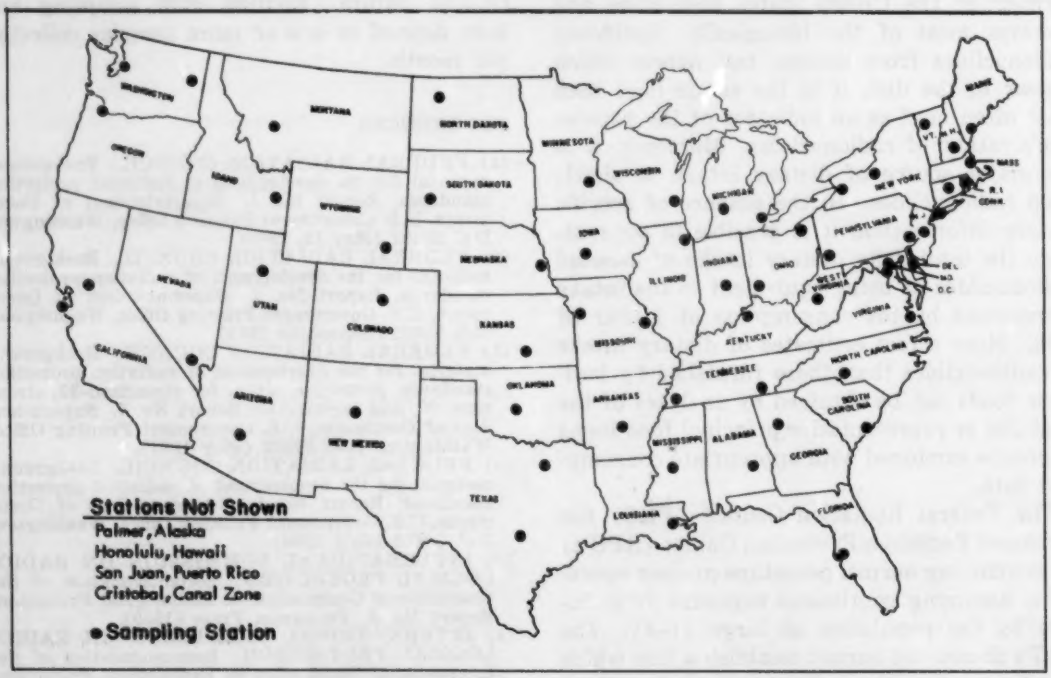

Figure 1. Pasteurized Milk Network sampling locations

from each milk processing plant in proportion to the plant's average sales in the community served. At most stations, the sample represents from 80 to 100 percent of the milk processed. Prior to September 15, 1961, the composite sample was taken from 1 day's sales per month and was as representative of the community's supply as was possible under practical conditions. Beginning with the resumption of nuclear weapons testing in the atmosphere in September 1961, and continuing through January 1963, samples were collected twice a week at nearly all stations and daily for short periods at selected stations. Since then, the sampling frequency has been reduced to once a week, except for the period May 15 through June 25, 1966, when samples were taken twice a week.

Samples are preserved with formaldehyde and sent to the PHS Southwestern (SWRHL), Southeastern (SERHL), or Northeastern (NERHL) Radiological Health Laboratories for analysis. Gamma analyses for iodine–131 are made within 3 to 6 days after sample collection, and any results exceeding 100 pCi/liter are immediately telephoned to appropriate State health officials for possible public health action. Analytical results are normally available 6 to 7 weeks after weekly samples are received by the laboratories.

Analytical procedures

Iodine–131, cesium–137, and barium–140 concentrations are determined by gamma-scintillation spectrometry.[1] After the weekly samples are gamma-scanned, samples from 2 consecutive weeks are composited and analyzed radiochemically to determine strontium–89 and strontium–90. With all such measurements, there is an inherent statistical variation. For the low radionuclide levels usually observed in milk and other environmental samples, this variation on a percentage basis is relatively high. It depends upon such factors as the method of chemical analysis, the sample counting rate and counting time, interferences from other radionuclides, and the background count. For milk samples, counting times of 50 minutes for gamma spectrometry and 30 to 50 minutes for beta determinations are used. Table 1 shows the approximate analytical errors (including counting error) associated with determinations of radionuclide concentrations in milk. These errors were determined by comparing results of a large number of replicate analyses.

The minimum detectable concentration is defined as the measured concentration equal to the two-standard deviation analytical error. Accordingly, the minimum detectable concentrations in units of pCi/liter are: strontium–89, 5; strontium–90, 2; cesium–137, 10; barium–140, 10; and iodine–131, 10. At these levels and below, the counting error comprises nearly all of the analytical error.

Calcium analyses at SERHL are done by an ion exchange and permanganate titration method, while at NERHL and SWRHL an ethylenediaminetetraacetic acid (EDTA) method is used.

Table 1. Analytical errors associated with determinations of radionuclide concentrations in milk

Nuclide	Concentration (pCi/liter)	Error [a] (pCi/liter)	Concentration (pCi/liter)	Error [a] (percent of concentration)
Iodine-131	Less than 100	10	100 or greater	10
Barium-140	Less than 100	10	100 or greater	10
Cesium-137	Less than 100	10	100 or greater	10
Strontium-89	Less than 50	5	50 or greater	10
Strontium-90	Less than 20	2	20 or greater	10

[a] Two standard deviations.

Data presentation

Table 2 presents summaries of the analyses for August 1966. Radionuclide concentrations below the minimum detectable level have been averaged using one-half the minimum detectable value. However, since October 1963, iodine–131 and barium–140 averages have been calculated on the basis of zero when concentrations below the minimum detectable level were observed. A similar procedure is used for the network average.

The distribution of monthly average strontium–90 and cesium–137 concentrations as observed in pasteurized milk for the months August 1965 and March through August 1966 are presented in tables 3 and 4. The average monthly strontium–90 concentrations in pasteurized milk from selected cities in the sampling program are presented in figure 2.

[1] Southeastern Radiological Health Laboratory employs a radiochemical procedure for barium–140 analysis.

Table 2. Average concentrations of radionuclides in pasteurized milk for the second quarter and August 1966 [a]

Sampling locations		Strontium-89 (pCi/liter)		Strontium-90 (pCi/liter)		Cesium-137 (pCi/liter)		Iodine-131 (pCi/liter)		Barium-140 (pCi/liter)	
		Second quarter [b]	August 1966	Second quarter	August 1966	Second quarter	August 1966	Second quarter	August 1966	Second quarter	August 1966
Ala:	Montgomery		<5	12	11	25	20	10	0	0	0
Alaska:	Palmer		<5	15	12	40	35	0	0	0	0
Ariz:	Phoenix		<5	3	3	10	15	0	0	0	0
Ark:	Little Rock		<5	32	24	40	25	40	0	10	0
Calif:	Sacramento		<5	9	5	15	10	0	0	0	0
	San Francisco		<5	9	4	20	15	0	0	0	0
C. Z:	Cristobal		<5	4	4	20	20	0	0	0	0
Colo:	Denver		<5	11	7	25	20	0	0	0	0
Conn:	Hartford		<5	13	11	40	30	0	0	0	0
Del:	Wilmington		<5	17	12	40	20	0	0	0	0
D.C:	Washington		<5	13	12	30	20	0	0	0	0
Fla:	Tampa		<5	10	11	125	145	0	0	0	0
Ga:	Atlanta		5	20	20	40	30	10	0	0	0
Hawaii:	Honolulu		<5	6	5	30	20	0	0	0	0
Idaho:	Idaho Falls		<5	14	15	40	20	0	0	0	0
Ill:	Chicago		<5	13	8	35	15	0	0	0	0
Ind:	Indianapolis		5	13	12	30	15	20	0	0	0
Iowa:	Des Moines		<5	16	12	30	15	10	0	0	0
Kans:	Wichita		<5	14	10	20	10	20	0	0	0
Ky:	Louisville		<5	19	15	20	10	0	0	0	0
La:	New Orleans		<5	32	33	45	65	0	0	0	0
Maine:	Portland		<5	16	13	70	50	0	0	0	0
Md:	Baltimore		<5	15	12	30	20	0	0	0	0
Mass:	Boston		<5	17	16	60	50	0	0	0	0
Mich:	Detroit		<5	12	8	30	20	0	0	0	0
	Grand Rapids		<5	16	11	45	25	0	0	0	0
Minn:	Minneapolis		<5	23	15	40	30	0	0	0	0
Miss:	Jackson		<5	26	20	30	25	10	0	0	0
Mo:	Kansas City		<5	17	12	25	10	30	0	0	0
	St. Louis		10	19	14	30	20	30	0	0	0
Mont:	Helena		<5	14	10	55	30	0	0	0	0
Nebr:	Omaha		<5	15	11	30	20	10	0	0	0
Nev:	Las Vegas		<5	6	4	25	10	0	0	0	0
N.H:	Manchester		<5	17	17	80	75	0	0	0	0
N.J:	Trenton		<5	13	11	30	20	0	0	0	0
N. Mex:	Albuquerque		<5	6	7	20	15	0	0	0	0
N.Y:	Buffalo		<5	12	10	40	25	0	0	0	0
	New York		<5	15	15	40	35	0	0	0	0
	Syracuse		<5	13	10	40	25	0	0	0	0
N.C:	Charlotte		<5	20	20	30	25	20	0	0	0
N. Dak:	Minot		<5	34	22	40	30	0	0	0	0
Ohio:	Cincinnati		<5	15	10	25	15	0	0	0	0
	Cleveland		<5	14	11	35	15	0	0	0	0
Okla:	Oklahoma City		<5	14	12	20	15	20	0	0	0
Ore:	Portland		<5	14	11	40	30	0	0	0	0
Pa:	Philadelphia		<5	14	12	35	20	0	0	0	0
	Pittsburgh		<5	19	15	45	30	0	0	0	0
P.R:	San Juan		<5	8	7	25	25	0	0	0	0
R.I:	Providence		<5	15	16	45	40	0	0	0	0
S.C:	Charleston		<5	21	20	50	50	20	0	0	0
S. Dak:	Rapid City		5	21	13	45	15	0	0	0	0
Tenn:	Chattanooga		<5	21	20	30	25	0	0	0	0
	Memphis		<5	19	16	20	10	20	0	0	0
Tex:	Austin		<5	6	5	15	10	0	0	0	0
	Dallas		<5	16	11	25	15	20	0	0	0
Utah:	Salt Lake City		<5	12	9	35	15	0	0	0	0
Vt:	Burlington		<5	14	13	50	35	0	0	0	0
Va:	Norfolk		<5	16	16	30	20	0	0	0	0
Wash:	Seattle		<5	18	17	55	50	0	0	0	0
	Spokane		<5	18	11	40	30	0	0	0	0
W. Va:	Charleston		<5	17	14	20	15	0	0	0	0
Wis:	Milwaukee		<5	10	8	40	20	0	0	0	0
Wyo:	Laramie		<5	12	8	30	15	0	0	0	0
Network average			<5	15.2	12.4	36	26	5	0	0	0

[a] Calcium analyses were discontinued as of March 1966.

[b] Quarterly averages are not reported since monthly averages for April were not calculated as only 10 percent of the samples were analyzed for strontium-89.

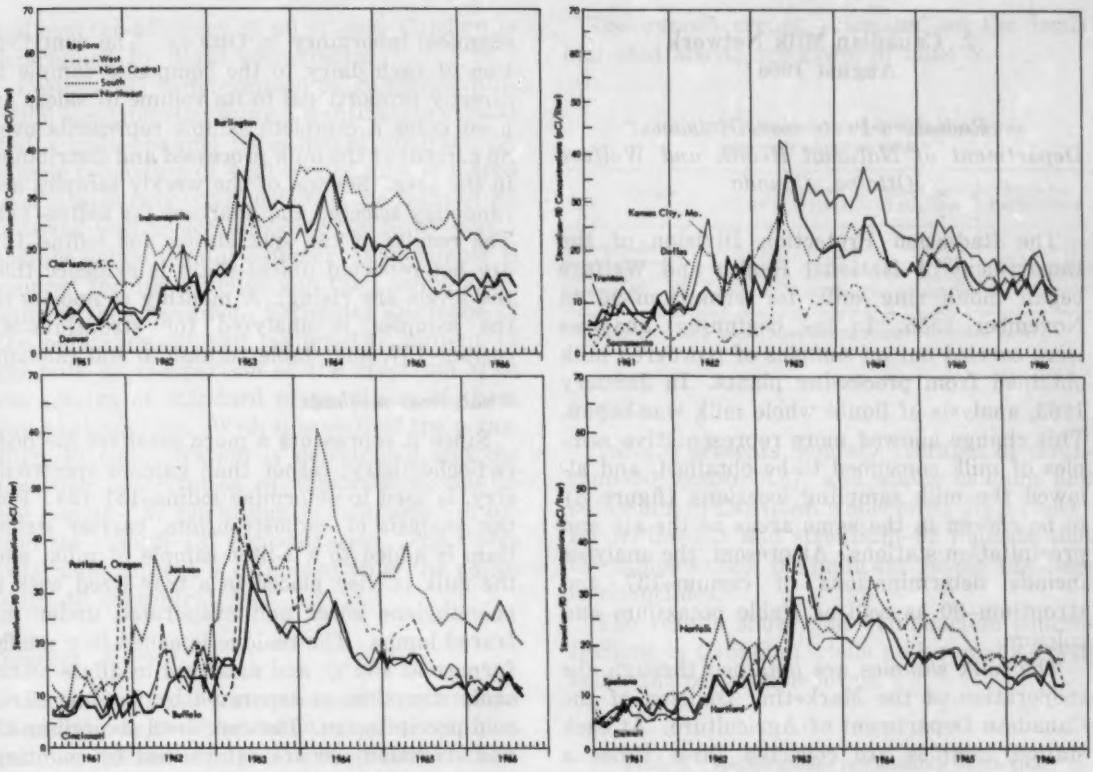

Figure 2. Strontium-90 concentrations in pasteurized milk, 1961–August 1966

Table 3. Frequency distribution, strontium-90 concentrations in milk at Pasteurized Milk Network stations, August 1965 and March–August 1966

Strontium-90 (pCi/liter)	Number of stations						
	1965	1966					
	Aug	Mar	Apr	May	June	July	Aug
Under 10	10	9	8	10	9	14	15
10–19	41	44	50	38	41	39	40
20–29	11	7	3	12	10	9	7
30–39	1	3	2	3	3	1	1

Table 4. Frequency distribution, cesium-137 concentrations in milk at Pasteurized Milk Network stations, August 1965 and March–August 1966

Cesium-137 (pCi/liter)	Number of stations						
	1965	1966					
	Aug	Mar	Apr	May	June	July	Aug
Under 50	45	56	55	51	56	56	56
50–99	16	6	7	11	6	6	6
100–149	1	1	1	1	1	1	1
150–199	1	0	0	0	0	0	0

2. Canadian Milk Network August 1966 [2]

Radiation Protection Division
Department of National Health and Welfare
Ottawa, Canada

The Radiation Protection Division of the Department of National Health and Welfare began monitoring milk for strontium–90 in November 1955. In the beginning, analyses were carried out on samples of powdered milk obtained from processing plants. In January 1963, analysis of liquid whole milk was begun. This change allowed more representative samples of milk consumed to be obtained, and allowed the milk sampling locations (figure 3) to be chosen in the same areas as the air and precipitation stations. At present, the analyses include determinations of cesium–137 and strontium–90 as well as stable potassium and calcium.

The milk samples are obtained through the cooperation of the Marketing Division of the Canadian Department of Agriculture. At each station samples are collected three times a week from selected dairies, combined into weekly composites, and forwarded to the radiochemical laboratory in Ottawa. The contribution of each dairy to the composite sample is directly proportional to its volume of sales. In most cases a complete sample represents over 80 percent of the milk processed and distributed in the area. Several of the weekly samples are randomly selected and analyzed for iodine–131. The results of the spot checks for iodine–131 are not reported unless there is evidence that the levels are rising. A monthly composite of the samples is analyzed for strontium–90, cesium–137, and stable potassium and calcium.

Analytical methods

Since it represents a more sensitive method, radiochemistry, rather than gamma spectrometry, is used to determine iodine–131 (*2*). For the analysis of radiostrontium, carrier strontium is added to a 1-liter sample of milk, and the milk is then placed in a tray lined with a polyethylene sheet and evaporated under infrared lamps. The residue is ashed in a muffle furnace at 450°C. and dissolved in dilute nitric acid; strontium is separated by fuming nitric acid precipitation. The combined strontium–89 and strontium–90 are determined by counting in a low-background beta counter. Strontium–90 is determined separately by extracting and counting its yttrium–90 daughter, while strontium–89 is estimated by difference from the total radiostrontium measurement. Appropriate corrections are made for self-absorption

[2] Prepared from information and data in the September 1966 monthly report "Data from Radiation Protection Programs," Canadian Department of National Health and Welfare, Ottawa, Canada.

Figure 3. Canadian milk sampling stations

and counter-efficiency at all stages. Calcium is determined by flame photometry.

Cesium–137 is determined by gamma-scintillation spectrometry using a scintillation crystal and a multi-channel pulse height analyzer. A sample consisting of 4.5 liters of milk is placed in a sample tray constructed in the form of an inverted well to accommodate the 5- by 4-inch sodium iodide crystal detector. The sample is counted for 100 minutes and the gamma spectrum is then recorded. Estimates are made of the potassium–40 and cesium–137 content of the milk by comparison of the spectrum with the spectra of standard preparations of these two radionuclides. With this method the potassium–40 concentration is determined and the Compton contribution of this radionuclide to the cesium–137 photopeak is subtracted to obtain the cesium–137 concentration. The stable potassium content is estimated from the potassium–40 concentration.

Sources of error

In the iodine and strontium determinations, tests indicate that the statistical error (95 percent confidence level) in the chemical operations involved is approximately plus-or-minus 10 percent. This value is independent of the concentration of the radionuclide in the milk because it depends only on the recovery of the carrier. In the determination of cesium–137 this factor is not involved.

The chemical procedures error must be combined with the counting error, which depends primarily on the concentration of the nuclide in the sample, the background radiation, and the length of time the sample and background are counted. This counting error has been evaluated mathematically for the particular counting arrangement used.

The overall errors, estimated on the basis indicated above, are given in table 5.

Table 5. Total error for various radionuclide concentrations in milk [a]

Nuclide	Error for 10 pCi/liter	Error for 50 pCi/liter	Error for 100 pCi/liter
Strontium-89	±25%	±20%	±15%
Strontium-90	±15%	±10%	±10%
Iodine-131	±50%	±20%	±10%
Cesium-137	±50%	±20%	±10%

[a] All errors are 2 σ values, representing 95-percent confidence levels.

Results

Table 6 presents monthly averages of strontium–90, cesium–137, and stable calcium and potassium in Canadian whole milk. Spot checks for iodine–131 and strontium–89 indicate that all samples had insignificant levels of these radionuclides.

The results show that radionuclide concentrations in Canadian whole milk remained well below the permissible levels.

Table 6. Radionuclides in Canadian whole milk August 1966

Station	Calcium (g/liter)	Potassium (g/liter)	Strontium-90 (pCi/liter)	Cesium-137 (pCi/liter)
Calgary	1.11	1.4	12.8	28
Edmonton	1.10	1.5	14.6	47
Ft. William	1.04	1.6	18.2	68
Fredericton	1.07	1.5	24.6	54
Ha ax	1.13	1.5	20.6	49
Montreal	1.08	1.5	12.7	32
Ottawa	1.12	1.5	10.0	28
Quebec	1.01	1.6	15.8	49
Regina	1.08	1.4	14.3	27
St. John's, Nfld	1.06	1.5	41.1	134
Saskatoon	1.14	1.5	13.8	27
Sault Ste. Marie	1.07	1.5	18.1	51
Toronto	1.09	1.6	7.2	24
Vancouver	1.17	1.5	21.2	81
Windsor	1.08	1.5	4.7	20
Winnipeg	1.06	1.5	12.1	28
Average	1.09	1.5	16.4	47

3. Pan American Milk Sampling Program August 1966

Pan American Health Organization and U.S. Public Health Service

In accordance with a joint agreement, the Pan American Health Organization (PAHO) and the U.S. Public Health Service (PHS) developed a collaborative program for furnishing assistance to health authorities in the Americas engaged in developing programs in radiological health.

Under this agreement, the PHS Division of Radiological Health furnishes to PAHO, on a loan basis, limited quantities of essential items of equipment and the requisite laboratory services to establish a surveillance program.

Sampling procedure

Initially, air sampling stations were established in Jamaica and Venezuela. In August 1963, the milk sampling program was begun with a milk sampling station in Caracas, Venezuela. Between April 1964 and August 1964, milk stations were added in Jamaica at Kingston, Montego Bay, and Mandeville. In July 1966, a station was added at Guayaquil, Ecuador (figure 4). Sampling varies according to local procedures.

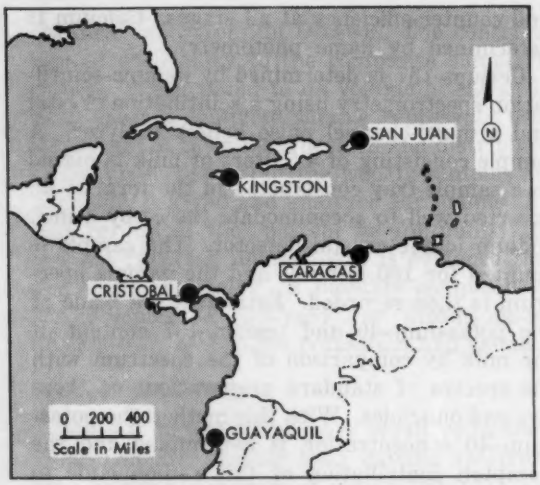

Figure 4. Pan American Milk Sampling Program stations

Under the direction of the Venezuelan Institute for Scientific Investigation, weekly samples are collected, preserved with formaldehyde, and composited monthly.

Jamaica, under the direction of the Ministry of Health, collects one monthly composite on a rotating basis from one of the three principal milk areas: Montego Bay (Montpelier), Mandeville, and Kingston (Spanish Town). All samples are sent to the PHS Southeastern Radiological Health Laboratory for analysis.

Table 7. Stable element and radionuclide concentrations in PAHO milk August 1966[b]

Sampling station		Number of samples	Calcium (g/liter)	Potassium (g/liter)	Strontium-90 (pCi/liter)	Cesium-137 (pCi/liter)	Barium-140 (pCi/liter)
Chile:	Santiago	1	1.04	1.60	10	5	<10
Colombia:	Bogota	4	1.08	1.51	3	5	<10
Ecuador:	Guayaquil	3	1.02	1.62	3	<5	<10
Jamaica:	Kingston[a]	1	1.20	1.39	13	205	<10
	Mandeville	1	1.08	1.32	8	140	10
	Montego Bay	NS	NS	NS	NS	NS	NS
Venezuela:	Caracas	1	1.11	1.32	4	5	<10
Canal Zone:	Cristobal		—	—	4	20	—
Puerto Rico:	San Juan		—	—	7	25	—

[a] Data from April 1966.
[b] Iodine-131 concentrations were less than 10 pCi/liter and strontium-89 concentrations were less than 5 pCi/liter for all samples.
NS, no sample collected.

Analytical procedures

Iodine–131 and cesium–137 are determined by gamma-scintillation spectrometry. Strontium–89, strontium–90, and barium–140 are determined radiochemically (*3*). Analytical errors are discussed in the "Analytical procedures, Pasteurized Milk Network."

Data presentation

Table 7 presents stable calcium and potassium, strontium–89, strontium–90, and cesium–137 monthly average concentrations. The monthly average of iodine–131 and barium–140 concentrations in milk were less than 10 pCi/liter.

For comparison purposes, the radionuclide concentrations at Cristobal, Canal Zone, and San Juan, Puerto Rico, are presented.

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(*2*) DASGUPTA, A. K., and H. G. GREEN. A method for the radiochemical determination of iodine–131 in milk, RPD–23. Radiation Protection Division, Department of National Health and Welfare, Ottawa, Canada (October 1963).

(*3*) PORTER, C., and B. KAHN. Improved determinations of strontium–90 in milk by an ion-exchange method. Anal Chem 36:676–678 (March 1964).

STATE MILK SURVEILLANCE ACTIVITIES

Considerable progress has been made by the State health departments in initiating or expanding environmental surveillance activities in radiological health. Many of the States have progressed to a state of comprehensive environmental surveillance programs and self-sustaining radiological health laboratories.

The continuing efforts of State health departments in the analysis and monitoring of radionuclides in milk complement Federal milk surveillance activities. State milk surveillance activities are continually undergoing developmental changes at this time. The results presented herein are representative of current surveillance activities directed at the use of milk as an indicator of dietary intake of radioactivity.

In addition to the State milk networks presented herein, programs previously covered in *Radiological Health Data and Reports* include:

State milk network	*Period reported*	*Last presented*
Colorado	May 1965–June 1966	October 1966
Connecticut	April–June 1966	November 1966
Florida	April–June 1966	October 1966
Indiana	April–June 1966	November 1966
Michigan	January–June 1966	November 1966
Minnesota	April–June 1966	November 1966
New York	January–June 1966	November 1966
Oklahoma	April–June 1966	October 1966
Pennsylvania	April–June 1966	November 1966
Texas	April–June 1966	October 1966

1. California Milk Network April–June 1966

Division of Environmental Sanitation
Department of Public Health
State of California

Surveillance of specific radionuclides in milk is one phase of the California Department of Health program on radiation control. This milk-monitoring function has been conducted at eight milksheds since January 1960 by the Department's Bureau of Radiological Health. With the addition of the Del Norte and Mendocino milksheds to the program in March 1962, weekly, biweekly, or monthly sampling of pasteurized milk has been conducted at 10 major milksheds (figure 1). The original sampling locations were chosen by the State Department of Agriculture so as to be representative of milk consumed by a high percentage of the State's population. A description of the various California milksheds was presented earlier by Heslep and Cornish (*1*).

Strontium–89 and strontium–90 concentrations are determined radiochemically. Potassium–40, iodine–131, cesium–137, and barium–140 in whole fluid milk are determined by gamma-scintillation spectrometry. A detailed description of the analytical procedures was presented earlier (*2*).

The monthly calcium and radionuclide concentrations in California pasteurized milk are given in table 1 for the period April to June 1966.

Network average strontium–90 and cesium–137 concentrations are presented graphically in figure 2.

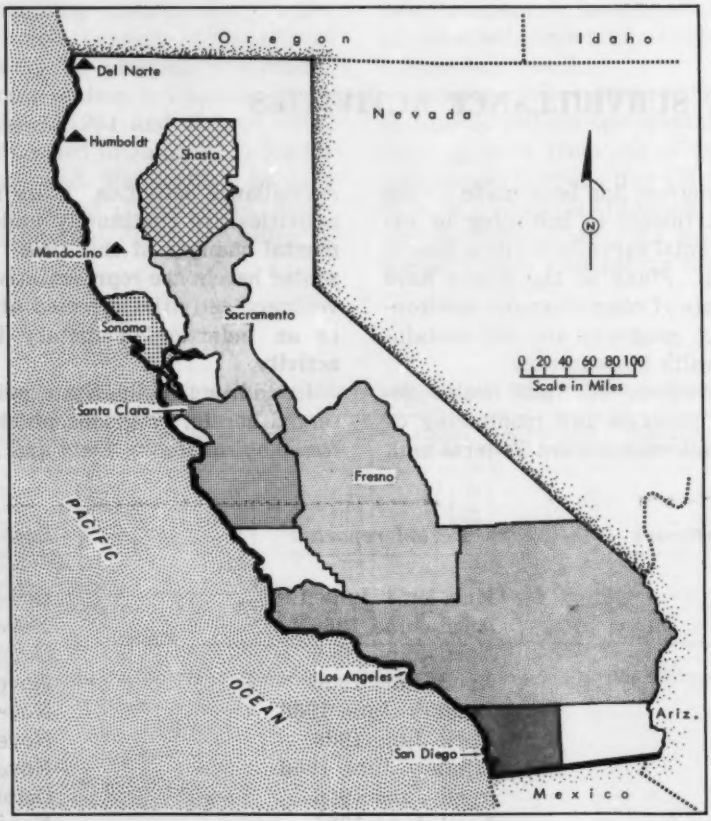

Figure 1. California milksheds

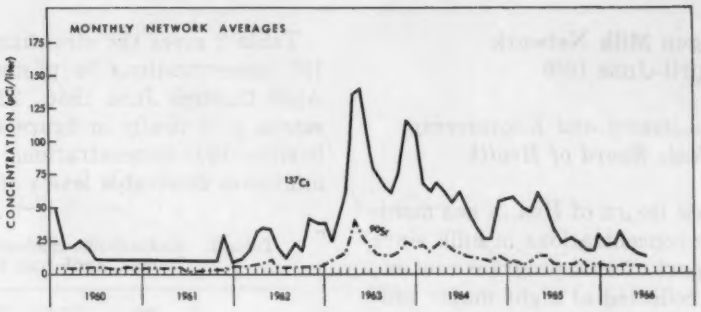

Figure 2. Radionuclide concentrations in California milk January 1960–June 1966

Table 1. Stable elements and radionuclides in California milk, April–June 1966

Element and month	Del Norte	Fresno	Humboldt	Los Angeles	Mendocino	Sacramento	San Diego	Santa Clara	Shasta	Sonoma	Average
Calcium, g/liter											
April	1.23	1.20	1.19	1.05	1.20	1.17	1.12	1.16	1.13	1.20	1.16
May	1.34	1.14	1.25	1.03	1.14	1.18	1.10	1.01	1.08	1.17	1.14
June	1.38	1.12	1.25	1.12	1.10	1.20	1.05	1.18	1.13	1.19	1.17
Potassium-40, pCi/liter											
April	1,200	1,190	1,130	1,360	1,240	1,160	1,260	1,190	1,210	1,250	1,230
May	1,200	1,210	1,160	1,330	1,220	1,270	1,200	1,310	1,200	1,230	1,230
June	1,180	1,240	1,160	1,280	1,260	1,270	1,210	1,340	1,240	1,300	1,250
Strontium-89, pCi/liter											
April	ND	NA	NA	NA	NA	NA	NA	ND	ND	NA	ND
May	ND	NA	ND	ND	ND	NA	NA	ND	0.6	NA	<0.1
June	15.0	ND	11.0	ND	4.2	0.9	<0.1	ND	2.0	1.5	3.5
Strontium-90, pCi/liter											
April	26.0	3.4	1.2	3.8	8.3	5.6	3.1	3.7	8.0	8.7	7.2
May	28.0	3.3	9.0	3.6	6.2	4.7	2.7	2.9	6.5	8.8	7.6
June	23.0	4.2	9.3	3.3	5.0	1.3	5.4	2.8	6.6	4.5	6.5
Cesium-137, pCi/liter											
April	45	13	21	12	15	17	*7	11	19	17	18
May	40	13	15	12	*7	10	16	15	12	12	15
June	37	13	16	*9	ND	*9	*5	*5	15	11	12

* When the counting rate of the sample is not equal to at least twice the 0.95 error, the value reported is the best available estimate, but is not statistically significant. Where no value is given, no activity was detected.
ND, not detectable
NA, no analysis performed

Previous coverage in *Radiological Health Data and Reports:*

Period	Issue
July–September 1963	March 1964
October–December 1963	June 1964
Annual summary 1964	June 1966
Annual summary 1965	June 1966
January–March 1966	September 1966

2. Oregon Milk Network April–June 1966

Division of Sanitation and Engineering
Oregon State Board of Health

The Oregon State Board of Health has monitored radionuclide concentrations in milk since March 1962. As part of this program routine, milk samples are collected at eight major production areas (figure 3), which supply 90 percent of the milk distributed in Oregon. Currently, pasteurized milk samples are collected monthly by the Oregon Department of Agriculture, except in the Portland area, where weekly samples are collected by the city of Portland. The milk sampling frequency is accelerated to a weekly basis in areas where iodine–131 concentrations exceed 100 pCi/liter, or where cesium–137 concentrations exceed 500 pCi/liter. Strontium–90 analyses are performed on a bimonthly basis, but may be done monthly when significant increases are observed.

Strontium–90 concentrations are determined using a trichloroacetic acid analytical procedure (*3*). Iodine–131, cesium–137, and barium–140 concentrations are determined by gamma-scintillation spectrometry (*4*).

Table 2 gives the strontium–90 and cesium–137 concentrations in pasteurized milk from April through June 1966. These data are presented graphically in figure 4. Iodine–131 and barium–140 concentrations remained below minimum detectable levels of 15 pCi/liter.

Table 2. Radionuclide concentrations in Oregon milk, April–June 1966

Sampling location	Sampling frequency	Strontium-90 (pCi/liter)			Cesium-137 (pCi/liter)		
		April	May	June	April	May	June
Baker	M	NS	10	NS	30	25	20
Coos Bay	M	NA	22	NS	90	40	45
Eugene	M	NA	10	NS	35	40	40
Medford	M	NS	6	NS	70	20	65
Nyssa	M	NS	7	NS	30	35	15
Portland composite	W	14	12	15	47	26	36
Portland local	W	NA	18	NA	51	53	43
Redmond	M	NA	9	NS	40	40	30
Tillamook	M	NA	28	NS	55	85	55
Average	------	14	14	15	50	38	38

M, sampled monthly
W, sampled weekly
NS, no sample collected
NA, no analysis

Previous coverage in *Radiological Health Data and Reports:*

Period	Issue
October–December 1964 and summary 1962–1964	June 1965
Annual summary 1965	June 1966
January–March 1966	September 1966

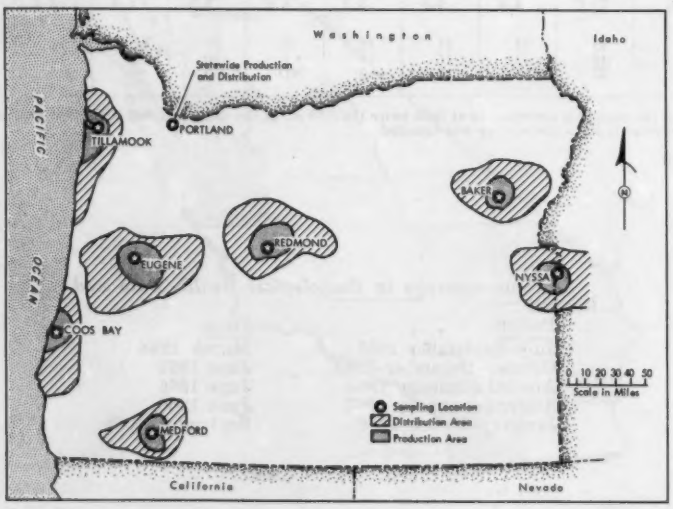

Figure 3. Oregon milk production and distribution areas

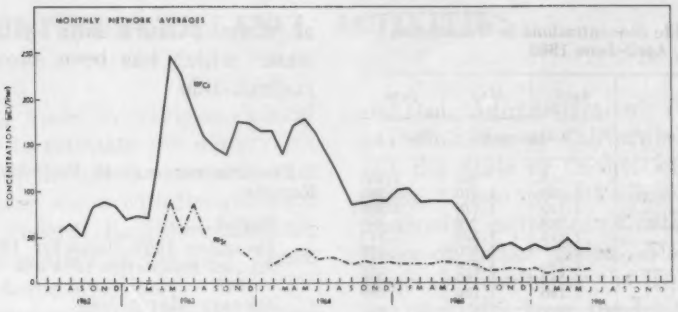

Figure 4. Radionuclide concentrations in Oregon milk network June 1962–June 1966

3. Washington Milk Network April–June 1966

Air Sanitation and Radiation Control Section
State of Washington Department of Health

The Washington State Department of Health initiated a surveillance program for radioactivity in raw milk in December 1962. The collection points shown in figure 5 were selected to provide samples representative of varying climatological conditions within the State's two major milksheds. In addition to the eight milk sampling locations in Washington, milk is sampled from Northwest Idaho (Sandpoint) as this area forms a part of the Spokane milkshed. Details of the sampling procedures were presented earlier (*5*).

Selected samples are analyzed radiochemically for strontium–90. Potassium–40, iodine–131, cesium–137, and barium–140 concentrations are determined by gamma-scintillation spectrometry. Details of the analytical procedures were presented earlier (*5*).

Table 3 presents monthly radionuclide concentrations in Washington raw milk for April through June 1966. During this period, iodine–131 and barium–140 concentrations remained below minimum detectable levels. Monthly average strontium–90 and cesium–137 concentrations are presented graphically in figure 6, so as to display general trends.

Zinc–65 in the Benton-Franklin area remained below minimum detectable levels during this period. This nuclide has periodically appeared in this area as a result of the irrigation

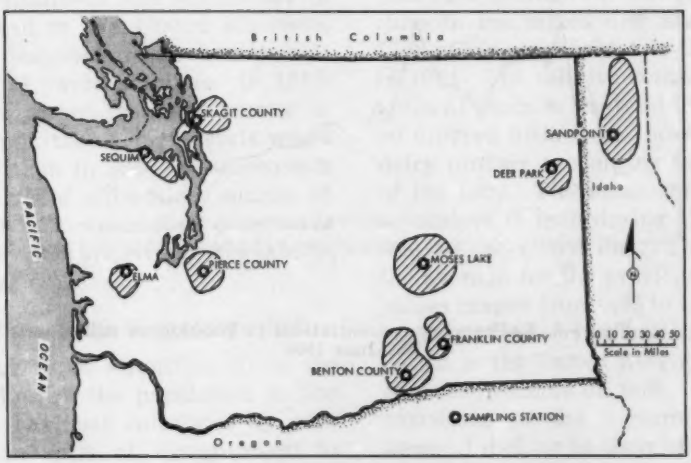

Figure 5. Washington milksheds and sampling locations

Table 3. Radionuclide concentrations in Washington milk, April–June 1966

Sampling location	April	May	June
	Potassium-40, pCi/liter		
Benton county	1,050	NS	1,250
Deer Park	1,190	1,210	1,260
Elma	1,120	1,170	1,260
Franklin County	NS	NS	NS
Moses Lake	1,210	1,320	1,210
Pierce County	1,260	1,170	1,170
Sandpoint	1,190	1,270	1,250
Sequim	1,140	1,180	NS
Skagit County	1,180	1,130	1,280
Average	1,170	1,210	1,240
	Strontium-90, pCi/liter		
Benton County	6	NS	6
Deer Park	11	13	13
Elma	11	14	20
Franklin County	NS	NS	NS
Moses Lake	7	7	7
Pierce County	8	11	15
Sandpoint	32	32	26
Sequim	11	14	NS
Skagit County	17	20	18
Average	13	16	15
	Cesium-137, pCi/liter		
Benton County	33	NS	25
Deer Park	42	45	43
Elma	44	63	37
Franklin County	NS	NS	NS
Moses Lake	21	17	19
Pierce County	33	46	74
Sandpoint	85	84	98
Sequim	52	63	NS
Skagit	63	54	54
Average	47	53	50

NS, no sample collected.

of some pasture land with Columbia River water which has been shown to contain this radionuclide.

Previous coverage in *Radiological Health Data and Reports:*

Period	Issue
December 1962–December 1963	May 1964
Annual summaries 1964 and 1965	June 1966
January–March 1966	September 1966

REFERENCES

(1) HESLEP, J. M., and A. C. CORNISH. California milk network and milkshed comparisons, April–June 1963. Radiol Health Data 4:596–599 (December 1963).

(2) STATE OF CALIFORNIA DEPARTMENT OF PUBLIC HEALTH. California milk network, 1960–June 1962. Radiol Health Data 4:90–92 (February 1963).

(3) MURTHY, G. K., J. E. COAKLEY, and J. E. CAMPBELL. A method for the elimination of ashing in strontium–90 determinations in milk. J Dairy Sci 43:151–154 (1960).

(4) OREGON STATE BOARD OF HEALTH, DIVISION OF SANITATION AND ENGINEERING. Oregon milk network, April–June 1965. Radiol Health Data 6:683–684 (December 1965).

(5) STATE OF WASHINGTON DEPARTMENT OF HEALTH, AIR AND RADIATION CONTROL SECTION, Washington milk network, January–June 1965. Radiol Health Data 6:619–621 (November 1965).

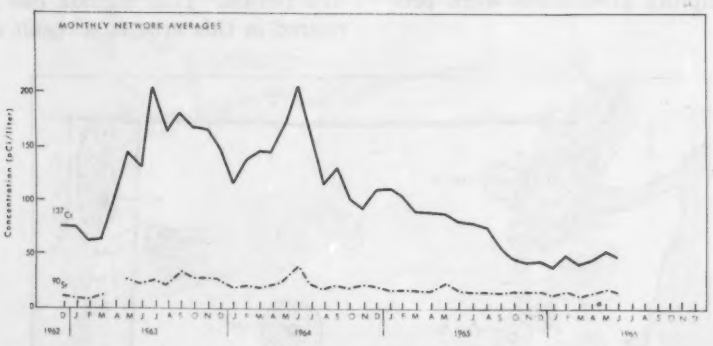
MONTHLY NETWORK AVERAGES
Concentration (pCi/liter)
200
150
100
50
0
137Cs
90Sr
D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1962
1963
1964
1965
1966

Figure 6. Radionuclide concentrations in Washington milk 1962–June 1966

FOOD AND DIET SURVEILLANCE ACTIVITIES

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuous basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in routine operation and reported periodically include: (1) the Public Health Service's Institutional Total Diet Sampling Network, (2) the Atomic Energy Commission's Tri-City Diet Study, (3) the Food and Drug Administration's Teenage Diet Study, (4) the State of California's Diet Study, and (5) the State of Connecticut's Standard Diet Study. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Also included in this issue are results for the United Kingdom Diet Survey, 1965, from the United Kingdom Agricultural Research Council Radiobiological Laboratory. Programs most recently reported in *Radiological Health Data and Reports* and not covered in this issue are listed below:

Program	Period reported	Last presented
California Diet	September–December 1965	September 1966
Connecticut Standard Diet	July 1965–June 1966	November 1966
Institutional Diet, PHS	January–March 1966	October 1966
Teenage Diet, FDA	February–November 1965	August 1966

1. Radionuclides in United Kingdom Diet 1965

Radiobiological Laboratory
United Kingdom Agricultural Research Council

Surveys of strontium–90 and cesium–137 in foodstuffs consumed in the United Kingdom, which have been described in previous reports in this series (*1,2*), were continued in 1965. Because it was apparent from the survey of radioactivity in milk that dietary levels would be lower in 1965 than in 1964, measurements were no longer made of some minor sources of contamination. Details of sampling procedures and full results for 1965 are given in the laboratory's latest report (*3*).

Content of strontium–90 in the average diet

The mean quantity of strontium–90 in the average mixed diet of the population in the United Kingdom has been calculated by multiplying the mean ratio of strontium–90 to calcium in different types of food by the quantities of calcium they contribute to the diet. The values for 1965 are given in table 1; they are compared in table 2 with results for previous years which were calculated in a similar manner.

The contamination of diet decreased during 1965; the average ratio of strontium–90 to calcium in the mixed diet during the year was 17.9 pCi/g, or about two-thirds of the value in 1964. The relative contributions of various kinds of foods to the total intake of strontium–90 differed little from those in previous years, dairy produce accounting for about 60 percent of the total. The mean ratio of strontium–90 to calcium in milk during 1965 was 1.06 times that in the mixed diet. This is very close to the average for the previous 7 years, when the values ranged from 0.95 to 1.2, and confirms the validity of inferring levels of dietary contamination in the United Kingdom from the results of measurements on milk. The significance of variations in the consumption of individual items of diet, or in their origin, is discussed in an earlier report (*2*).

Cesium–137 in milk and meat

It has been explained previously (*2*) that the radiation dose to man caused by cesium–137 in diet is best assessed from whole-body measurements and that dietary surveys are to be regarded only as supplementary. Results from past years have shown that milk and meat are the principal sources of cesium–137 in diet, together accounting for about 60 to 80 percent of the total intake; in 1965, therefore, measurements of cesium–137 were made only on these two foodstuffs.

The countrywide average concentration of cesium–137 in milk, weighted according to production in the different areas, was 98 pCi/liter in 1965, which is about one third lower than the value in the previous year. The mean level of cesium–137 in home-produced and imported meat consumed in the United Kingdom during 1965 was about 280 pCi/kg compared with 490 pCi/kg in 1964. It may be inferred therefore, that the total dietary intake of cesium–137 during 1965 was also about one third lower than in 1964.

Table 1. Mean content of strontium-90 in the diet in the United Kingdom, 1965

Origin	Mean daily intake of calcium [a] (mg)	Mean ratio $^{90}Sr/Ca$ (pCi/g)	Estimated daily intake of ^{90}Sr (pCi)
Dairy produce:			
Milk and cream	515	19.0	9.78
Cheese	104	21.1	2.19
Vegetables and fruit:			
Root vegetables	25	55.9	1.40
Leaf and other vegetables	36	26.3	0.95
Fruit, etc	17	26.3	0.45
Flour and cereals	[b] 244	11.6	2.83
Meat	23	38.0	0.87
Other sources:			
Drinking water	60	—	0.95
Miscellaneous	60	—	—
Total mixed diet	1,084	17.9	19.42

[a] Values computed by the Ministry of Agriculture, Fisheries, and Food from surveys of domestic food consumption. The values differ slightly from those used to calculate the daily intake in previous years.
[b] This includes about 201 mg mineral calcium added to flour as *creta praeparata*.

Table 2. Comparison of levels of strontium-90 in the United Kingdom diet, 1958–1965

Food item	1958	1959	1960	1961	1962	1963	1964	1965
	Mean $^{90}Sr/Ca$ ratio, pCi/g							
Total diet (including drinking water and tea) [a]	5.9	9.0	6.4	6.2	9.9	22.8	25.9	17.9
Milk and cream	7.0	9.8	6.4	5.9	11.7	25.6	28.0	19.0
Cheese	7.7	7.5	5.3	4.8	8.7	19.7	24.7	21.1
Root vegetables	14.2	23.2	19.6	24.3	25.1	53.1	48.4	55.9
Leaf vegetables and fruit	8.7	14.3	8.5	10.3	17.6	35.4	30.6	26.3
Flour and cereals	15.9	28.0	22.7	21.8	18.4	71.9	[b] 17.4	[b] 11.6
Eggs	-------	9.0	6.3	-------	6.2	12.0	27.6	-------
	Intake of strontium-90, pCi/day							
Total diet	6.4	9.8	6.9	6.7	10.7	24.7	28.5	19.4
	Percentage of total [c]							
Milk and cream	54.3	49.7	45.7	43.7	54.2	51.4	52.0	50.4
Cheese	11.4	7.3	7.2	6.9	7.7	7.6	9.0	11.3
Root vegetables	5.5	5.9	7.1	9.1	5.9	5.4	4.2	7.2
Leaf vegetables and fruit	8.5	9.0	7.5	9.5	10.2	8.9	5.7	7.2
Flour and cereals	11.7	13.5	15.4	15.2	8.0	13.7	15.1	14.6
Other foodstuffs	5.0	5.6	5.3	5.2	5.3	4.9	6.3	4.5
Drinking water	3.6	4.4	5.2	3.7	3.8	3.4	3.7	4.9
Tea	-------	4.6	6.5	6.7	4.9	4.7	3.9	-------

[a] Account has been taken of mineral calcium (*creta praeparata*) added to flour.
[b] In contrast to previous years, the values for 1964 and 1965 are based on the analysis of flour to which mineral calcium as *creta praeparata* had been added. The values for these 2 years comparable with those for previous years, when only the natural calcium was present in the samples analyzed, would be about 100 pCi/g and 70 pCi/g, respectively.
[c] Tea was not sampled in 1958 and 1965, so the percentages for these years are not strictly comparable with the others.

2. Strontium–90 in Tri-City Diets February–April 1966 [1]

Health and Safety Laboratory
U.S. Atomic Energy Commission

Since March 1960, the Health and Safety Laboratory, U.S. Atomic Energy Commission, through its quarterly diet study, has made estimates of the strontium–90 content of the average diet of individuals living in New York City, San Francisco, and Chicago.

Selected foods representing 19 food categories are purchased at each of these 3 cities every 3 months on a staggered basis (that is, New York City, February 1966; San Francisco, March 1966; and Chicago, April 1966) and are analyzed for strontium–90. Fourteen of the diet categories are analyzed on a quarterly basis. Eggs, poultry, fresh fish, shellfish, and meat are purchased quarterly, but analyzed annually. This policy was initiated in 1965 due to the lower concentrations of strontium–90 in these food categories. The contribution of these five diet categories to the total annual intake of strontium–90 over the last 4 years has been approximately 5 percent. Therefore, this figure is used to calculate their contribution to the total strontium–90 dietary intake. These values are added to contributions of the other 14 food categories to obtain quarterly estimates of annual strontium–90 intake at the 3 cities. Consumption figures used are based upon data from the Department of Agriculture (*4*).

Some food types are assumed to be representative of larger food categories, such as liquid milk for dairy products in general.

The consumption data are based on a weight-as-purchased basis. Before the food samples for the Tri-City Study are ashed for radiochemical analysis, they are prepared to a certain degree as if for actual consumption. For example, fruits are peeled, eggs are shelled, and poultry is boned. Therefore, concentrations of radioactivity in foods as reported in the Tri-City Diet Study are based on the trimmed weight. No correction is made for the waste.

After two samplings at each city, it was found that the calcium content of most food categories did not vary among cities, nor did it vary significantly with time. Calcium analyses of dietary components were performed for the third time recently, and further confirmed this result (*5*). Calcium analyses were therefore discontinued and the average calcium content of foods was computed and used to estimate the average annual intake of this material. Details of the sampling system and a discussion of the results obtained have been summarized (*6*).

Results of the February to April 1966 sampling are presented in table 3. The variation

[1] Data from Fallout Program Quarterly Summary Report, HASL–173. Available from the Clearinghouse for Federal Scientific and Technical Information, CFSTI, 5285 Port Royal Road, Springfield, Virginia 22151.

Table 3. Average dietary consumption and strontium-90 intake in Tri-City diet, February–April 1966

Food category	Diet (kg/yr)	Calcium (g/yr)	New York City February 1966		San Francisco March 1966		Chicago April 1966	
			(pCi/kg)	(pCi/yr)	(pCi/kg)	(pCi/yr)	(pCi/kg)	(pCi/yr)
Bakery products	37	37.0	16.9±1.0	625	10.8±0.9	400	12.6±0.9	466
Whole grain products	11	10.0	33.9±1.6	373	23.5±1.1	259	18.3±1.0	201
Fresh vegetables	43	15.0	12.5±0.4	538	2.5±0.2	108	12.8±0.3	550
Root vegetables	17	6.1	10.2±0.3	173	14.5±0.5	247	8.8±0.4	150
Milk	221	234.4	13.2±0.7	2,917	7.2±0.4	1,591	11.1±0.4	2,453
Flour	43	8.6	18.0±0.4	774	7.1±0.3	305	16.3±0.6	701
Macaroni	3	0.7	8.9±0.4	27	8.8±0.3	26	11.3±0.4	34
Rice	3	1.1	2.3±0.4	7	1.6±0.3	5	2.4±0.2	7
Dried beans	3	2.9	21.5±1.7	65	19.7±1.5	59	24.7±1.6	74
Fresh fruit	68	12.6	2.7±0.3	184	2.2±0.2	150	4.4±0.3	299
Potatoes	45	5.8	11.8±0.6	531	3.0±0.3	135	6.6±0.4	297
Canned fruit	26	1.3	1.9±0.1	49	1.6±0.1	42	1.8±0.2	47
Fruit juices	19	1.7	9.5±0.4	371	2.0±0.2	38	4.1±0.3	78
Canned vegetables	20	4.2	12.4±1.0	248	2.6±0.3	52	8.5±0.4	170
Meat, fish, poultry, shellfish, and eggs	99	42.0		* 362		* 180		* 291
Annual intake		383		7,244		3,597		5,818
Daily intake		1.05		19.8		9.9		15.9
pCi strontium-90/g Ca				18.9		9.4		15.2

* Estimated as 5 percent of total intake.

with time of the daily intake of strontium–90 in the three cities is plotted in figure 1. A discussion of cesium–137 intakes as reflected in the Tri-City Diet Study was presented elsewhere (*7*).

Previous coverage in *Radiological Health Data and Reports:*

Period	Issue
Sixteenth sampling (February 1964–April 1964)	December 1964
Seventeenth sampling (July–September 1964)	March 1965
Eighteenth sampling (August–October 1964)	June 1965
Nineteenth sampling (November 1964–January 1965)	September 1965
Twentieth sampling (February–April 1965)	December 1965
Twenty-first sampling (May–July 1965)	March 1966
Twenty-second sampling (August–October 1965)	June 1966
Twenty-third sampling (November 1965–January 1966)	September 1966

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(*1*) AGRICULTURAL RESEARCH COUNCIL RADIOBIOLOGICAL LABORATORY. Strontium–90 in diet in the United Kingdom, 1958–1961. Radiol Health Data 4:134–137 (March 1963).

(*2*) BRUCE, R. S. Radionuclides in the United Kingdom Diet, 1962–1964. Radiol Health Data Rep 7: 331–334 (June 1966).

(*3*) AGRICULTURAL RESEARCH COUNCIL RADIOBIOLOGICAL LABORATORY. Report ARCRL 16 (1966).

(*4*) U. S. DEPARTMENT OF AGRICULTURE. Food consumption of households in the United States, household food consumption survey, 1955, Report No. 1. Superintendent of Documents, Government Printing Office, Washington, D. C. 20402 (December 1956).

(*5*) U. S. ATOMIC ENERGY COMMISSION. Fallout program quarterly summary report HASL–144:281–287. Office of Technical Services, Department of Commerce, Washington, D.C. 20230 (April 1, 1964). Summarized in Radiol Health Data 5:285–288 (June 1964).

(*6*) RIVERA, J., and J. H. HARLEY. HASL contributions to the study of fallout in food chains, HASL–147. Office of Technical Services, Department of Commerce, Washington, D.C. 20230 (July 1, 1964).

(*7*) RIVERA, J. Dietary intakes and body burdens of cesium–137. Radiol Health Data 6:504–506 (September 1965).

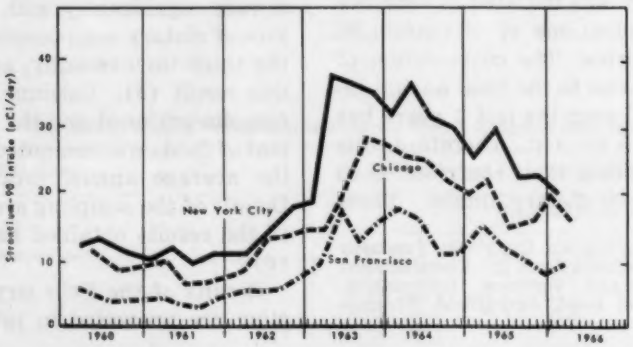

Figure 1. Daily intake of strontium–90 in Tri-City diet 1960–April 1966

Section II. Water

The Public Health Service, the Federal Water Pollution Control Administration, and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These Standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*), set the limits for approval of a drinking water supply containing radium–226 and strontium–90 as 3 pCi/liter and 10 pCi/liter, respectively. Limits may be higher if total intake of radioactivity from all sources indicates that such intakes are within the guides recommended by FRC for control action. In the known absence [1] of strontium–90 and alpha emitters, the limit is 1,000 pCi/liter gross beta activity, except when more complete analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water programs previously reported in *Radiological Health Data and Reports* are listed below.

[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha emitters and strontium–90, respectively.

REFERENCES

(*1*) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, Revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

(*2*) FEDERAL RADIATION COUNCIL. Radiation protection guidance for Federal agencies. Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Program	Period reported	Last presented
Colorado River Basin Sampling Network	1962–1964	November 1965
Drinking Water Analysis Program	1962	October 1965
Florida Water Sampling Program	1964	November 1965
Kentucky Water Sampling Program	May 1963–June 1964	March 1965
Lower Columbia River Radiological Survey in Oregon	August 1963–July 1964	October 1965
Minnesota Surface Water Sampling Program	July–December 1965	July 1966
New York Water Sampling Program	June–December 1965	June 1966
North Carolina Water Sampling Program	1964	November 1965
Radiostrontium in Tap Water, HASL	May and July–November 1965	June 1966
Washington Surface Water Sampling Program	July 1964–June 1965	May 1966

GROSS RADIOACTIVITY IN SURFACE WATERS OF THE UNITED STATES, JUNE 1966

Division of Pollution Surveillance
Federal Water Pollution Control Administration
Department of Interior

The monitoring of levels of radioactivity in surface waters of the United States was begun in 1957 as a part of the Federal Water Pollution Control Administration's Water Pollution Surveillance System. Table 1 presents the current preliminary results of the alpha and beta analysis. The radioactivity associated with dissolved solids provides a rough indication of the levels which would occur in treated water, since nearly all suspended matter is removed by treatment processes. Strontium–90 results are reported quarterly. The stations on each river are arranged in the table according to their distance from the headwaters. Table 1 indicates the average total beta activity in suspended-plus-dissolved solids in raw water collected at each station. A description of the sampling and analytical procedures was published in the June 1966 issue of *Radiological Health Data and Reports.*

Complete data and exact sampling locations are published in annual compilations (*1–6*) or are available on request.

Special note is taken when the alpha radioactivity is 15 pCi/liter or greater or when the beta radioactivity is 150 pCi/liter or greater. These arbitrary levels provide a basis for the selection of certain data and for comment on the data, if needed. They reflect no public health significance as the Public Health Service drinking water standards have already provided the basis for this assessment. Changes from or toward these arbitrary levels are also noted in terms of changes in radioactivity per unit weight of solids. No discussion of gross radioactivity per gram of dissolved or sus-

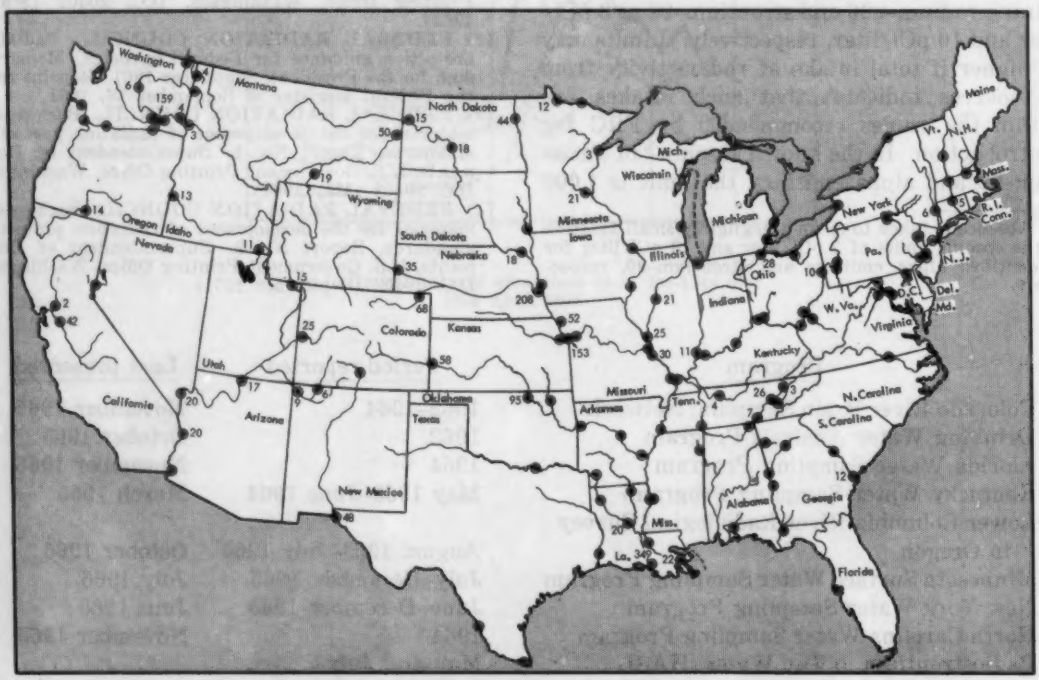

Figure 1. Sampling locations and associated total beta activity (pCi/liter) in surface waters, June 1966

pended solids for all stations of the Water Pollution Surveillance System will be attempted at this time. Comments are made only on monthly average values. Occasional high values from single weekly samples may be absorbed into a relatively low average. When these values are significantly high, comment will be made.

During May and June, the following stations showed alpha radioactivity in excess of 15 pCi/liter on dissolved or suspended solids: Platte River: Plattsmouth, Nebraska; North Platte River: Henry, Nebraska; and South Platte River: Julesburg, Colorado.

During June, the dissolved or suspended alpha radioactivity increased to more than 15 pCi/liter on the following stations: Arkansas River: Coolidge, Kansas; San Joaquin River: Vernalis, California; Atchafalaya River: Morgan City, Louisiana: and Mississippi River: Kansas, Missouri. Morgan City, Louisiana also showed a beta radioactivity on suspended solids of more than 150 pCi/liter.

REFERENCES:

(1) PUBLIC HEALTH SERVICE, DIVISION OF WATER SUPPLY AND POLLUTION CONTROL. National water quality network annual compilation of data, PHS Publication No. 663, 1958 Edition. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.
(2) *Ibid.*, 1959 Edition.
(3) *Ibid.*, 1960 Edition.
(4) *Ibid.*, 1961 Edition.
(5) *Ibid.*, 1962 Edition.
(6) PUBLIC HEALTH SERVICE, DIVISION OF WATER SUPPLY AND POLLUTION CONTROL. Water pollution surveillance system, annual compilation of data, PHS Publication No. 663 (Revised), 1963 Edition. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

Table 1. Radioactivity in raw surface waters, June 1966

Station	Average beta activity (pCi/liter)			Average alpha activity (pCi/liter)			Station	Average beta activity (pCi/liter)			Average alpha activity (pCi/liter)		
	Suspended	Dissolved	Total	Suspended	Dissolved	Total		Suspended	Dissolved	Total	Suspended	Dissolved	Total
Animas River:							Missouri River:						
Cedar Hill, N. Mex.	2	4	6	0	1	1	Williston, N. Dak.	3	12	15	1	3	4
Arkansas River:							Bismarck, N. Dak.	1	17	18	0	3	3
Coolidge, Kans.	17	41	58	5	16	21	Yankton, S. Dak.	1	17	18	0	3	3
Ponca City, Okla.	73	22	95	7	1	8	St. Joseph, Mo.	30	22	52	6	3	9
Atchafalaya River:							Kansas City, Kans.	132	21	153	37	4	41
Morgan City, La.	335	14	349	121	1	122	North Platte River:						
Bear River:							Henry, Nebr.	4	31	35	<1	17	17
Preston, Idaho	1	10	11	0	2	2	Ohio River:						
Big Horn River:							Toronto, Ohio	2	8	10	0	0	0
Hardin, Mont.	2	17	19	<1	8	8	Pend Oreille River:						
Chena River:							Albeni Falls Dam, Idaho	1	3	4	0	<1	<1
Fairbanks, Alaska	10	2	12	2	<1	2	Platte River:						
Clearwater River:							Plattsmouth, Nebr.	191	17	208	39	2	41
Lewiston, Idaho	1	2	3	0	0	0	Rainy River:						
Clinch River:							Baudette, Minn.	2	10	12	0	0	0
Clinton, Tenn.	0	3	3	0	0	0	Red River, North:						
Kingston, Tenn.[a]	9	17	26	<1	1	1	Grand Forks, N. Dak.	5	39	44	1	5	6
Colorado River:							Red River, South:						
Loma, Colo.	8	17	25	1	6	7	Alexandria, La.	8	12	20	2	1	3
Page, Ariz.	3	14	17	0	5	5	Rio Grande:						
Boulder City, Nev.	3	17	20	1	5	6	El Paso, Tex.	13	35	48	4	8	12
Parker Dam, Calif-Ariz.	1	19	20	0	5	5	Sacramento River:						
Columbia River:							Greens Landing, Calif.	0	2	2	0	0	0
Wenatchee, Wash.	1	5	6	0	0	0	San Joaquin River:						
Pasco, Wash.[a]	82	77	159	0	<1	<1	Vernalis, Calif.	8	34	42	3	18	21
Connecticut River:							San Juan River:						
Enfield Dam, Conn.	1	4	5	0	0	0	Shiprock, N. Mex.	2	7	9	<1	2	2
Cumberland River:							Savannah River:						
Cheatham Lock, Tenn.	0	4	4	0	0	0	Port Wentworth, Ga.[a]	6	6	12	1	0	1
Great Lakes:							Snake River:						
Duluth, Minn.	0	3	3	0	0	0	Payette, Idaho	3	10	13	1	4	5
Green River:							Wawawai, Wash.	1	3	4	0	0	0
Dutch John, Utah	<1	15	15	0	3	3	South Platte River:						
Hudson River:							Julesburg, Colo.	9	59	68	1	35	36
Poughkeepsie, N.Y.	1	5	6	0	0	0	Tennessee River:						
Illinois River:							Chattanooga, Tenn.	0	7	7	0	0	0
Peoria, Ill.	4	17	21	1	3	4	Truckee River:						
Grafton, Ill.	8	17	25	1	4	5	Farad, Calif.	0	1	1	0	0	0
Klamath River:							Wabash River:						
Keno, Ore.	1	13	14	0	<1	<1	New Harmony, Ind.	1	10	11	0	2	2
Maumee River:							Yellowstone River:						
Toledo, Ohio	0	28	28	0	5	5	Sidney, Mont.	42	8	50	4	1	5
Mississippi River:							Maximum	335	77	349	121	35	122
St. Paul, Minn.	3	18	21	0	2	2							
E. St. Louis, Ill.	17	13	30	4	3	7	Minimum	0	1	1	0	0	0
New Orleans, La.	10	12	22	3	2	5							

[a] Gross beta activity at this station may not be directly comparable to gross beta activity at other station because of the possible contribution of radionuclides from an upstream nuclear facility in addition to the contribution from fallout and naturally occurring radionuclides, common to all stations.

RADIOSTRONTIUM IN TAP WATER, NOVEMBER 1965–JUNE 1966 [1]

Health and Safety Laboratory
U.S. Atomic Energy Commission

The Health and Safety Laboratory has performed analyses for strontium–90 in tap water at New York City since August 1954. Samples of tap water are collected daily so that by the end of the month a composite of at least 100 liters is available for analysis. Cesium–137 determinations were begun in January 1964. The analytical methods used at the laboratory are given in the Health and Safety Laboratory Manual of Standard Procedures (*1*).

Strontium–90 concentration and cesium–137/strontium–90 ratios in New York City tap water for November 1965 through June 1966 are presented in table 1. These results appear graphically in figure 1.

A decreasing trend has been observed in the strontium–90 concentrations since the July 1963 peak. The maximum strontium–90 concentrations observed are below the acceptable limit as set forth in the interstate carrier drinking water standards (*2*).

[1] Prepared from information appearing in Fallout Program Quarterly Summary Report, HASL 173. This report is available from the Clearinghouse for Federal Scientific and Technical Information, CFSTI, 5285 Port Royal Road, Springfield, Virginia 22151.

Table 1. Radiostrontium in New York City tap water November 1965–June 1966

Date	Strontium-90 [a] (pCi/liter)	Cesium-137/ strontium-90
1965		
November	1.10	0.18
December	1.61	0.11
1966		
January	1.90	0.23
February	1.45	[b]
March	1.54	[b]
April	0.58	[b]
May	1.19	[b]
June	1.62	[b]

[a] Approximately 100 liters per sample; [b] No ratio reported

REFERENCES

(*1*) U.S. ATOMIC ENERGY COMMISSION. Manual of standard procedures 40:E–38–01–16, Health and Safety Laboratory, U.S. Atomic Energy Commission, 376 Hudson Street, New York 14, New York.

(*2*) FEDERAL REGISTER RULES AND REGULATIONS. Title 42–Public Health, Chapter 1, Public Health Service, Department of Health, Education, and Welfare; Part 72, Interstate Quarantine, Subpart J, Drinking Water Standards 27:2154–5. Superintendent of Documents, Government Printing Office, Washington, D.C. 20402 (March 6, 1962).

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
January–June 1965	December 1965
May and July–November 1965	June 1966

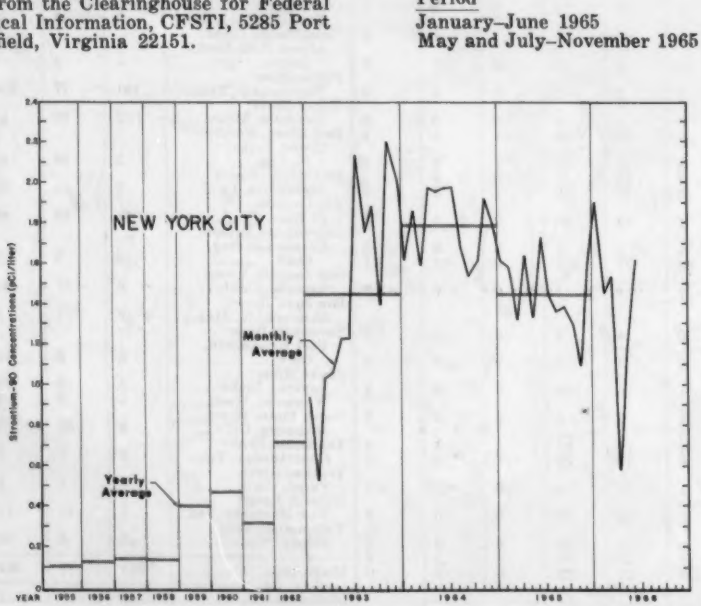

Figure 1. Strontium–90 concentrations in New York City tap water

Section III. Air and Deposition

RADIOACTIVITY IN AIRBORNE PARTICULATES AND PRECIPITATION

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product activity. To date, this surveillance has been confined chiefly to gross beta analysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the U.S. Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

An intercomparison of the above networks was performed by Lockhart and Patterson (*1*) in 1962. In addition to those programs presented in this issue, the following program was previously covered in *Radiological Health Data and Reports*:

Network	Period reported	Last presented
HASL Fallout Network	July–December 1965	September 1966

1. Radiation Surveillance Network August 1966

Division of Radiological Health
Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Surveillance Network (RSN) which regularly gathers samples from 74 stations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

Daily samples of airborne particulates and precipitation are forwarded to the Radiation Surveillance Network Laboratory in Rockville, Maryland, for laboratory analysis. The alerting function of the network is provided by routine field estimates of the gross beta activity made by the station operators prior to submission of the samples for laboratory analysis. When high air levels are reported, appropriate officials are promptly notified. Compilation of field estimates and laboratory confirmations are reported elsewhere on a monthly basis (*2*). A detailed description of the sampling and analytical procedures was presented in the November 1966 issue of *Radiological Health Data and Reports*.

Table 1 presents the monthly average gross beta activity in surface air and deposition by precipitation during August 1966. Time profiles of gross beta in air for eight RSN stations are shown in figure 2. Gamma spectroscopy analysis was performed on 308 air samples.

Figure 1. Radiation Surveillance Network sampling stations

Table 1. Gross beta activity in surface air and precipitation, August 1966

Station location		Number of samples		Air surveillance (gross beta activity, pCi/m³)			Last profile in *RHD&R*	Precipitation	
		Air	Pptn	Maximum	Minimum	Average [a]		Total depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	28	8	0.12	<0.10	<0.10	Nov 66	57	<12
Alaska:	Adak	31		<0.10	<0.10	<0.10	June 66	[b]	
	Anchorage	23	10	<0.10	<0.10	<0.10	Mar 66	50	<10
	Attu Island	30		<0.10	<0.10	<0.10	July 66	[b]	
	Fairbanks	21	4	<0.10	<0.10	<0.10	Apr 66	13	<3
	Juneau	23	20	<0.10	<0.10	<0.10	July 65	234	<47
	Kodiak	6		<0.10	<0.10	<0.10	May 66	[b]	
	Nome	28		<0.10	<0.10	<0.10	Sept 66	[b]	
	Pt. Barrow	29		<0.10	<0.10	<0.10	Aug 66	[b]	
	St. Paul Islands	31		<0.10	<0.10	<0.10	Oct 66	[b]	
Ariz:	Phoenix	29		0.12	<0.10	<0.10	July 65	[b]	
Ark:	Little Rock	15	11	0.12	<0.10	<0.10	Dec 66	214	<43
Calif:	Berkeley	27	1	<0.10	<0.10	<0.10	May 66	3	<1
	Los Angeles	23		<0.10	<0.10	<0.10	Sept 66	[b]	
C.Z:	Ancon	18		<0.10	<0.10	<0.10	May 66	[b]	
Colo:	Denver	29	5	<0.10	<0.10	<0.10	May 66	28	<7
Conn:	Hartford	31	6	0.11	<0.10	<0.10	Apr 66	44	<9
Del:	Dover	22		0.12	<0.10	<0.10	Nov 66	[b]	
D.C:	Washington	28	4	0.12	<0.10	<0.10	Aug 66	40	<8
Fla:	Jacksonville	31	10	<0.10	<0.10	<0.10	Dec 66	186	<37
	Miami	29	9	<0.10	<0.10	<0.10	Apr 66	108	<22
Ga:	Atlanta	12	3	0.13	<0.10	<0.10	Oct 66	82	<16
Guam:	Agana	27		<0.10	<0.10	<0.10	Nov 66	[b]	
Hawaii:	Honolulu	31	1	<0.10	<0.10	<0.10	July 66	16	<3
Idaho:	Boise	28		0.13	<0.10	<0.10	July 66	[b]	
Ill:	Springfield	30	6	0.15	<0.10	<0.11	Aug 66	85	<17
Ind:	Indianapolis	28	3	0.17	<0.10	<0.11	Oct 66	35	<7
Iowa:	Iowa City	31	1	<0.10	<0.10	<0.10	May 66	5	<1
Kans:	Topeka	31	4	0.11	<0.10	<0.10	Mar 66	81	<16
Ky:	Frankfort	28	8	0.17	<0.10	<0.11	Aug 66	59	<12
La:	New Orleans	29	14	<0.10	<0.10	<0.10	Aug 66	259	<54
Maine:	Augusta	31	9	0.14	<0.10	<0.10	Sept 66	87	<17
	Presque Isle	25	8	0.15	<0.10	<0.10	May 66	47	<10
Md:	Baltimore	22	1	0.15	<0.10	<0.11	Apr 66	9	<2
	Rockville	15		0.11	<0.10	<0.10	July 66	[b]	
Mass:	Lawrence	31	6	0.13	<0.10	<0.10	Nov 66	30	<6
	Winchester	31	7	0.11	<0.10	<0.10	June 66	43	<9
Mich:	Lansing	31	7	0.14	<0.10	<0.10	July 66	54	<11
Minn:	Minneapolis	21	5	<0.10	<0.10	<0.10	Nov 66	128	<26
Miss:	Jackson	24	4	0.12	<0.10	<0.10	Sept 66	47	<9
Mo:	Jefferson City	31	6	0.13	<0.10	<0.10	Oct 66	31	<6
Mont:	Helena	29	5	0.14	<0.10	<0.11	June 66	12	<3
Nebr:	Lincoln	18	7	0.21	<0.10	<0.12	Oct 66	91	<18
Nev:	Las Vegas	28		0.12	<0.10	<0.10	Apr 66	[b]	
N.H:	Concord	20		0.13	<0.10	<0.11	Aug 66	[b]	
N.J:	Trenton	31	2	0.14	<0.10	<0.10	Sept 66	3	<1
N. Mex:	Santa Fe	25	9	<0.10	<0.10	<0.10	June 66	81	<16
N.Y:	Albany	22	7	<0.10	<0.10	<0.10	Oct 66	32	<6
	Buffalo	29		0.13	<0.10	<0.10	May 66	[b]	
	New York City	30		<0.10	<0.10	<0.10	June 66	[b]	
N.C:	Gastonia	31	10	0.13	<0.10	<0.10	May 66	45	<9
N. Dak:	Bismarck	31	6	0.12	<0.10	<0.10	Aug 66	109	<22
Ohio:	Cincinnati	17		<0.10	<0.10	<0.10	Nov 66	[b]	
	Columbus	30	8	0.28	<0.10	<0.15	Sept 66	109	<22
	Painesville	31	10	0.13	<0.10	<0.11	Apr 66	118	<24
Okla:	Oklahoma City	28	5	<0.10	<0.10	<0.10	July 66	125	<25
	Ponca City	24	9	<0.10	<0.10	<0.10	Apr 66	70	<14
Ore:	Portland	31	3	<0.10	<0.10	<0.10	Oct 66	16	<3
Pa:	Harrisburg	26	2	<0.10	<0.10	<0.10	Oct 66	30	<6
P.R:	San Juan	23	7	0.11	<0.10	<0.10	Sept 66	111	<22
R.I:	Providence	28	5	<0.10	<0.10	<0.10	July 66	66	<13
S.C:	Columbia	28	7	<0.10	<0.10	<0.10	June 66	133	<27
S. Dak:	Pierre	31	4	0.12	<0.10	<0.10	July 65	55	<11
Tenn:	Nashville	31	8	0.12	<0.10	<0.10	July 66	112	<23
Tex:	Austin	31	8	0.11	<0.10	<0.10	Nov 66	101	<21
	El Paso	29	6	<0.10	<0.10	<0.10	Aug 66	54	<11
Utah:	Salt Lake City	30	3	0.21	<0.10	<0.12	Sept 66	6	<1
Vt:	Barre	26	10	0.16	<0.10	<0.10	Dec 66	126	<26
Va:	Richmond	31	6	<0.10	<0.10	<0.10	Dec 66	33	<7
Wash:	Seattle	31	1	<0.10	<0.10	<0.10	Mar 66	3	1
	Spokane	29	1	0.12	<0.10	<0.10	Nov 66	1	<1
W. Va:	Charleston	31	9	0.14	<0.10	<0.10	June 66	68	<14
Wis:	Madison	27	4	0.11	<0.10	<0.10	Dec 66	98	<20
Wyo:	Cheyenne	31	8	0.14	<0.10	<0.10	Apr 66	62	<12
Network summary		1,987	351	0.28	<0.10	<0.10		70	<14

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values of <0.10 are assumed to be 0.10 for averaging purposes. If 10 percent or more samples from a station contain <0.10 pCi/m³, a less-than sign is placed before the average.
[b] No precipitation sample collected.

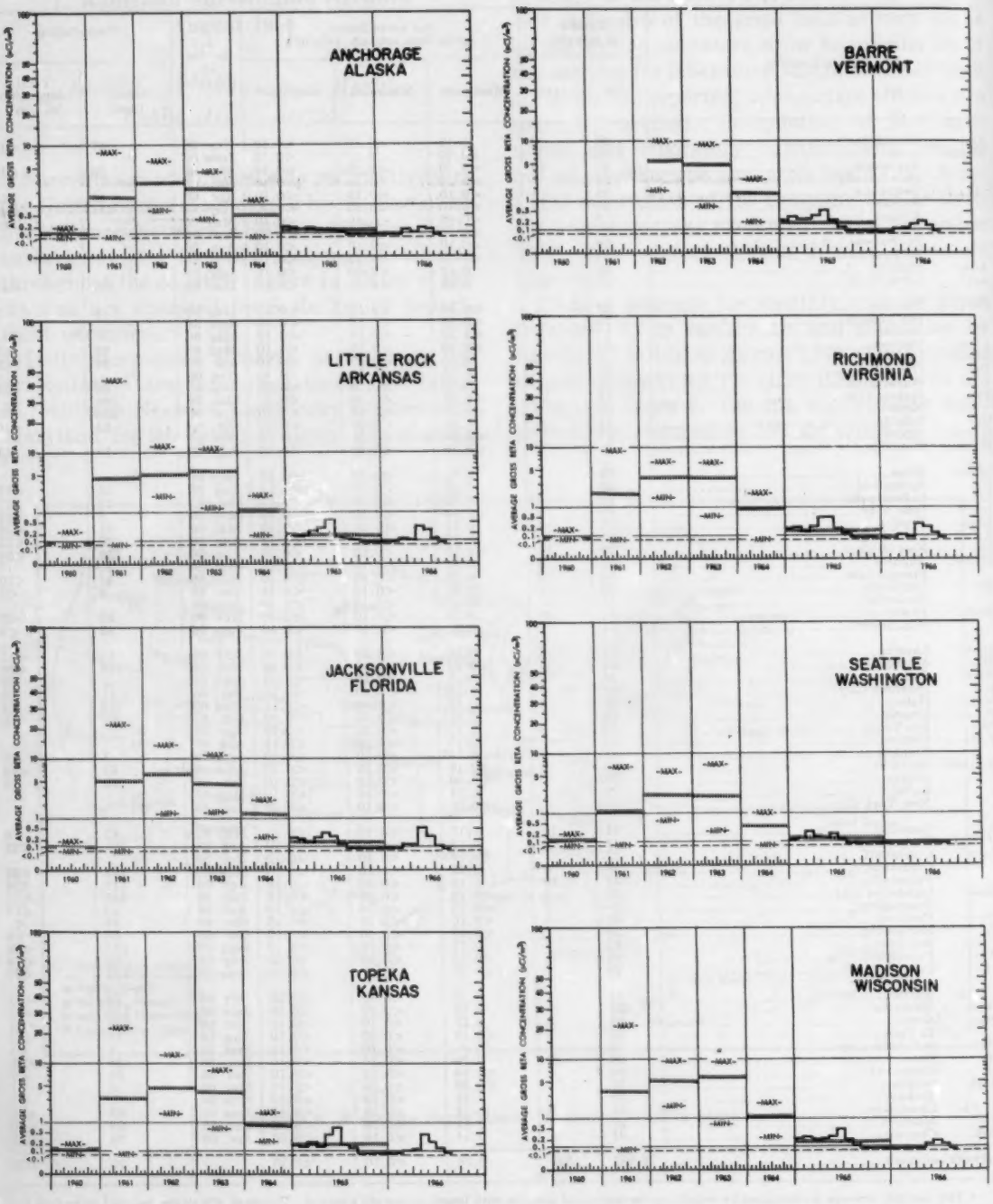

Figure 2. Monthly and yearly profiles of beta activity in air, Radiation Surveillance Network, 1960–August 1966

2. Canadian Air and Precipitation Monitoring Program, August 1966 [1]

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 3), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the Radioactive Fallout Study Program are contained in reports of the Department of National Health and Welfare (*3–7*).

A summary of the sampling procedures and methods of analysis was presented in the November 1966 issue of *Radiological Health Data and Reports.*

[1] Prepared from information and data in the September 1966 monthly report "Data from Radiation Protection Program," Canadian Department of National Health and Welfare, Ottawa, Canada.

Surface air and precipitation data for August 1966 are presented in table 2.

Table 2. Canadian gross beta activity in surface air and precipitation, August 1966

Station	Air surveillance				Precipitation measurements	
	Number of samples	Activity, pCi/m³			Average concentrations (pCi/liter)	Total deposition (nCi/m²)
		Maximum	Minimum	Average		
Calgary	31	0.2	0.0	0.1	102	3.1
Coral Harbour	31	0.1	0.0	0.0	56	3.6
Edmonton	31	0.2	0.0	0.1	42	4.3
Ft. Churchill	31	0.1	0.0	0.1	70	1.2
Ft. William	31	0.2	0.0	0.1	14	1.6
Fredericton	31	0.2	0.0	0.1	40	1.5
Goose Bay	31	0.1	0.0	0.0	17	1.5
Halifax	31	0.1	0.0	0.1	28	1.9
Inuvik	31	0.1	0.0	0.1	31	0.8
Montreal	31	0.2	0.0	0.1	34	4.1
Moosonee	30	0.1	0.0	0.1	NS	NS
Ottawa	30	0.2	0.0	0.1	26	2.2
Quebec	30	0.2	0.0	0.1	30	3.9
Regina	31	0.2	0.0	0.1	40	2.3
Resolute	30	0.1	0.0	0.0	39	1.5
St. John's, Nfld	31	0.1	0.0	0.1	13	1.6
Saskatoon	31	0.2	0.0	0.1	44	2.1
Sault Ste. Marie	31	0.2	0.0	0.1	47	3.1
Toronto	31	0.2	0.0	0.1	27	1.6
Vancouver	31	0.1	0.0	0.1	37	1.1
Whitehorse	30	0.2	0.0	0.0	27	1.4
Windsor	31	0.2	0.0	0.1	24	3.0
Winnipeg	31	0.2	0.0	0.1	49	5.1
Yellowknife	30	0.2	0.0	0.1	153	0.8
Network summary		0.2	0.0	0.1	43	2.3

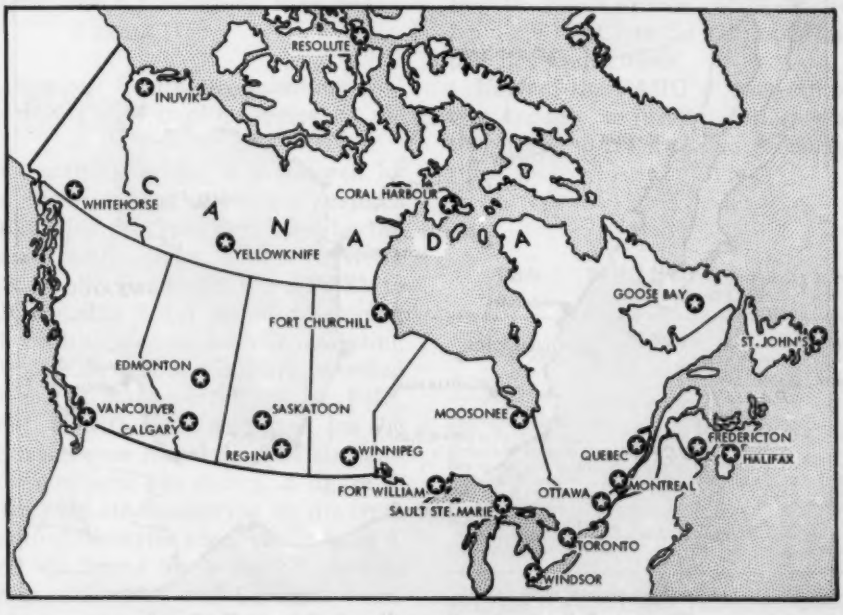

Figure 3. Canadian air and precipitation sampling stations

3. Mexican Air Monitoring Program July and August 1966

National Commission of Nuclear Energy

The Radiation Surveillance Network of Mexico was established by the Comisión Nacional de Energía Nuclear (CNEN), México, D.F. From 1952 to 1961, the network was directed by the Institute of Physics of the University of Mexico, under contract to the CNEN.

In 1961, the CNEN appointed its Division of Radiological Protection to establish a new Radiation Surveillance Network. In 1966, the Division of Radiological Protection was restructured and its name changed to Dirección General de Seguridad Radiológica (DRS). The network consists of 16 stations (figure 4), 11 of which are located at airports and operated by airline personnel. The remaining five stations are located at México, D.F., Mérida, Veracruz, San Luis Potosí, and Ensenada. Staff members of the DRS operate the station at México, D.F., while the other four stations are manned by members of the Centro de Previsión del Golfo de México, the Chemistry Department of the University of Mérida, the Institute de Zonas Deserticas of the University of San Luis Potosí, and the Escuela Superior de Ciencias Marinas of the University of Baja California, respectively.

Sampling

The sampling procedure involves drawing air through a high-efficiency 6- by 9-inch glass-fiber filter for 20 hours a day, 3 or 4 days a week at the rate of 1,000 cubic meters per day using high-volume samplers.

Table 3. Mexican gross beta activity of airborne particulates, July 1966

Station	Number of samples	Gross beta activity, pCi/m³		
		Maximum	Minimum	Average
Acapulco	13	0.1	<0.1	0.1
Chihuahua	12	1.0	0.1	0.4
Ciudad Juárez	9	0.4	<0.1	0.3
Ensenada	13	0.4	0.1	0.2
Guadalajara	16	0.7	<0.1	0.1
Guaymas	3	0.1	0.1	0.1
La Paz	17	0.5	<0.1	0.2
Matamoros	7	0.4	<0.1	0.2
Mazatlán	15	0.5	<0.1	0.2
Mérida	12	0.6	<0.1	0.3
México, D.F.	15	1.1	<0.1	0.3
Nuevo Laredo	12	1.5	0.1	0.3
San Luis Potosí	12	0.4	<0.1	0.1
Tampico	13	0.5	<0.1	0.1
Torreón	9	1.3	0.1	0.3
Veracruz	13	1.7	<0.1	0.4

Figure 4. Fallout network sampling stations in Mexico

After each 20-hour sampling period, the filter is removed and shipped via airmail to the Sección de Radioactividad Ambiental, CNEN, in México, D.F., for assay of gross beta activity, allowing a minimum of 3 or 4 days after collection for the decay of radon and thoron. The data are not extrapolated to the time of collection. Statistically, it has been found that a minimum of eight samples per month were needed to get a reliable average activity at each station (*8*).

The maximum, minimum, and average fission product beta concentrations in surface air during July and August 1966 are presented in tables 3 and 4.

Table 4. Mexican gross beta activity of airborne particulates, August 1966

Station	Number of samples	Gross beta activity, pCi/m³		
		Maximum	Minimum	Average
Acapulco	12	0.3	<0.1	0.1
Chihuahua	16	0.5	<0.1	0.1
Ciudad Juárez	15	0.4	<0.1	0.1
Ensenada	9	0.4	<0.1	0.1
Guadalajara	14	0.3	<0.1	0.1
Guaymas	3	0.6	0.1	0.4
La Paz	8	0.1	<0.1	<0.1
Matamoros	5	0.1	0.1	0.1
Mazatlán	10	0.2	<0.1	0.1
Mérida	15	0.3	<0.1	0.1
México, D.F.	9	0.6	<0.1	0.2
Nuevo Laredo	12	0.7	<0.1	0.2
San Luis Potosí	15	0.6	<0.1	0.1
Tampico	17	0.5	0.1	0.1
Torreón	19	0.9	<0.1	0.2
Veracruz	15	0.4	<0.1	0.2

4. Pan American Air Sampling Program August 1966

Pan American Health Organization and U.S. Public Health Service

Gross beta activity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the U.S. Public Health Service (PHS) to assist PAHO-member countries in developing radiological health programs. The sampling equipment and analytical services are provided by the Division of Radiological Health, PHS, and are identical with those employed for the Radiation Surveillance Network. The air sampling station positions are shown in figure 5.

The August 1966 air monitoring results from the participating countries are given in table 5. Average and maximum levels for all stations except Bogota, Colombia, and Caracas, Venezuela, have decreased markedly from July levels. Bogota and Caracas increased very slightly from <0.10 pCi/m³ to <0.11 pCi/m³ and <0.12 pCi/m³, respectively.

None of the PAHO August samples were active enough to justify gamma scanning and, therefore, no fresh fission products were identified.

Table 5. PAHO gross beta activity in surface air August 1966

Station location	Number of samples	Gross beta activity, pCi/m³		
		Maximum	Minimum	Average[a]
Argentina: Buenos Aires	13	0.37	<0.10	<0.16
Chile: Santiago	22	0.55	<0.10	<0.22
Colombia: Bogota	22	0.27	<0.10	<0.11
Ecuador: Guayaquil	28	0.26	<0.10	<0.11
Jamaica: Kingston	23	<0.10	<0.10	<0.10
Peru: Lima	20	0.51	<0.10	<0.23
Venezuela: Caracas	20	0.26	<0.10	<0.12
West Indies: Trinidad	19	0.15	<0.10	<0.10
Pan American summary	167	0.55	<0.10	<0.14

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values of <0.10 are assumed to be 0.10 for averaging purposes. If 10 percent or more of the samples from a station contain <0.10 pCi/m³, a less-than sign is placed before the average.

Figure 5. Pan American Air Sampling Program stations

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(*3*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report of 1959 on the Radioactive Fallout Study Program, CNHW–RP–3. Department of National Health and Welfare, Ottawa, Canada (May 1960).

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Section IV. Other Data

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included are such data as those obtained from human bone sampling, bovine thyroid sampling, and environmental monitoring reports.

STRONTIUM-90 IN HUMAN BONE, OCTOBER-DECEMBER 1965 [1]

Division of Radiological Health
Public Health Service

To obtain data on the concentration of strontium–90 in man by age and geographical region, the Public Health Service began collecting human bone specimens in late 1961. The target population includes children and young adults up to 25 years of age. Since strontium–90 in measurable amounts has been present in the global environment for more than a decade and major calcium accretion ceases by age 17 or 18, persons over 25 years old are of limited interest in the program. This has been confirmed by analyses of selected samples of people in older age groups, the results having shown their bone strontium–90 content to be low and age-independent (*1*).

Although a few samples come from living persons as a result of surgical procedures, the majority are obtained post mortem. In the latter case, the specimens are limited to accident victims or persons who have died of an acute disease process that was not likely to impair bone metabolism. For analytical purposes, a sample of at least 100 grams of wet bone is desired. Generally, this amount is readily available for older children, but it presents some difficulties from the standpoint of infants and children under 5 years of age.

Most specimens received to date have been vertebrae and ribs. Efforts to collect long bones for comparison of results with British data have not been successful.

Laboratory procedures

The bones are analyzed at the Northeastern Radiological Health Laboratory of the Division of Radiological Health, at Winchester, Massachusetts. Sample collection and preparation are explained elsewhere (*2*). Strontium–90 is measured by TBP extraction of its yttrium daughter, which is precipitated as an oxalate. The strontium–90 content is then calculated (*3*) from the yttrium–90 activity. For the purpose of maintaining analytical reproducibility, "blind" duplicate analyses are performed on 10 to 20 percent of the samples. To maintain analytical accuracy, pools of simulated "spiked" bone ash are analyzed in replicate on a continuing basis, and cross-checks with outside laboratories are conducted periodically.

The results of laboratory analyses for strontium–90 in individual bones from persons dying during the last quarter of 1965 are presented in table 1 in order of increasing age within each sampling region. The sampling regions have been defined in an earlier report (*5*). The data are reported as picocuries of strontium–90 per gram of ash (the primary determination), per gram of calcium (for comparision with other data and for purposes of model development), and per gram of bone (as a rough indication of

[1] Period during which death of the donor occurred.

Table 1. Strontium-90 in human bone, deaths during October–December 1965

Location of sample by region and State	Sex	Bone type [a]	Age at death [b] (years)	Strontium-90, pCi/g of:			
				Ash	2 σ error	Calcium	Bone
Northeast:							
N.Y.	M	V	0 (7 mo)	1.07	0.15	3.06	0.08
Mass.	F	V	2	1.65	0.17	4.64	0.16
N.Y.	M	V	3	1.42	0.15	3.68	0.20
N.J.	M	V	3	0.97	0.10	2.69	0.09
N.Y.	M	V	4	1.15	0.17	3.21	0.07
N.Y.	F	V	5	0.82	0.08	2.14	0.09
Mass.	M	V	6	1.26	0.11	3.52	0.10
N.Y.	M	V	7	0.96	0.10	2.62	0.11
N.Y.	F	V	8	0.79	0.11	2.25	0.05
Mass.	M	V	9	0.87	0.07	2.29	0.08
Mass.	F	V	12	0.93	0.07	2.62	0.08
Mass.	F	V	13	1.90	0.11	5.77	0.18
Mass.	M	V	15	1.26	0.08	3.44	0.13
N.Y.	M	V	16	1.22	0.08	3.12	0.14
Mass.	M	V	19	0.68	0.07	1.74	0.10
Mass.	M	V	19	0.87	0.08	1.94	0.15
Mass.	M	V	19	0.93	0.09	2.32	0.15
Vt.	M	V	20	0.85	0.06	2.18	0.13
Mass.	M	V	20	1.09	0.07	2.82	0.15
Mass.	M	V	24	1.07	0.10	2.75	0.15
N.Y.	F	V	24	0.67	0.06	1.73	0.08
Southeast:							
Md.	M	V	7	0.88	0.11	2.45	0.09
Ky.	M	V	8	1.09	0.14	2.99	0.10
Md.	M	V	17	0.85	0.08	2.21	0.13
Md.	M	V	19	1.00	0.07	2.63	0.13
Ky.	F	V	19	0.80	0.08	2.15	0.10
Ky.	M	V	22	1.08	0.09	2.77	0.15
Central:							
Ohio	M	V	0 (5 mo)	1.69	0.20	4.92	0.13
Ohio	F	V	0 (9 mo)	2.31	0.24	6.61	0.18
Ohio	M	V	1	1.46	0.16	4.00	0.14
Ohio	M	V	2	1.59	0.14	4.34	0.15
Ohio	F	V	2	1.21	0.15	3.38	0.11
Ohio	F	V	3	1.37	0.14	3.81	0.13
Minn.	F	V	5	0.89	0.11	2.43	0.08
Minn.	F	V	5	2.18	0.16	5.90	0.18
Ohio	M	V	6	0.75	0.10	2.04	0.06
Ohio	M	V	6	0.75	0.07	2.11	0.07
Ohio	F	V	6	0.69	0.07	1.73	0.18
Ohio	M	V	7	1.11	0.12	2.88	0.19
Minn.	M	V	9	1.05	0.15	2.92	0.08
Minn.	M	V	11	0.84	0.09	2.29	0.07
Ohio	M	V	13	1.10	0.09	2.80	0.25
Ohio	F	V	13	0.87	0.07	2.36	0.09
Ohio	M	V	14	1.07	0.09	2.56	0.19
Minn.	M	V	16	0.81	0.09	2.14	0.09
Minn.	F	V	17	0.53	0.07	1.37	0.08
Minn.	F	V	18	0.60	0.07	1.54	0.08
Ohio	M	V	20	1.04	0.10	2.60	0.20
Ohio	M	V	21	0.75	0.10	1.90	0.13
Ohio	M	V	22	0.77	0.07	2.00	0.16
Ohio	M	V	22	0.77	0.09	1.94	0.16
Ohio	M	V	23	0.52	0.07	1.31	0.10
Ohio	M	V	23	0.53	0.06	1.36	0.09
Ohio	F	V	23	0.41	0.06	1.01	0.08
Ohio	M	V	23	0.82	0.07	2.08	0.14
Ohio	M	V	24	0.86	0.09	2.17	0.14
Ohio	M	V	25	0.89	0.08	2.41	0.08
Delta:							
La.	M	V	1	2.07	0.16	5.69	0.22
La.	M	V	1	1.02	0.12	2.76	0.11
La.	F	V, S	1	1.27	0.15	3.60	0.09
La.	F	V, S	3	1.89	0.15	5.19	0.17
La.	M	V	10	1.07	0.14	2.94	0.10
La.	F	V, R	17	0.43	0.05	1.32	0.09
La.	F	V, R	17	0.89	0.07	2.33	0.11
La.	M	R	23	0.59	0.05	1.43	0.19
La.	M	V, R	24	1.16	0.09	3.02	0.19
Southwest:							
Calif.	M	V, R	1	1.69	0.13	4.81	0.11

[a] Type of bone: V, vertebrae
R, rib
S, sternum

[b] Age given as of last birthday prior to death.

dose). Two-sigma counting errors are reported for the ash concentration. Table 2 summarizes all available data from 1961 through 1965.

Following the pattern of earlier reports, subsequent articles will continue to provide interpretation of the data at appropriate stages in the program (*2–4*).

Previous coverage in *Radiological Health Data and Reports:*

Period	Issue
Deaths through 1964	April 1966
First quarter 1965	June 1966
Second quarter 1965	September 1966
Third quarter 1965	October 1966

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Table 2. Strontium-90 in human bone samples for 5-year age groups, 1961–1965

Age group [a]	Year of death [b]	Number	Strontium-90/calcium (pCi/g)		
			Mean [c]	Minimum	Maximum
0–4 years	1961	3	2.7	1.8	3.4
	1962	50	3.3	0.8	9.7
	1963	44	4.5	1.0	13.0
	1964	67	4.4	1.0	8.7
	1965	68	3.9	0.7	8.9
5–9 years	1961	1	2.7	—	—
	1962	33	2.7	1.0	9.4
	1963	43	3.9	1.8	9.1
	1964	64	3.6	1.2	7.0
	1965	47	2.9	1.3	6.4
10–14 years	1961	4	1.8	1.2	2.8
	1962	28	2.1	0.8	3.5
	1963	47	2.9	1.1	9.0
	1964	56	3.1	0.9	5.7
	1965	38	2.8	1.1	5.8
15–19 years	1961	0	—	—	—
	1962	31	2.2	0.9	4.6
	1963	73	2.6	1.0	7.0
	1964	58	2.9	1.2	8.0
	1965	56	2.3	1.3	4.7
20–24 years	1961	0	—	—	—
	1962	29	1.8	0.9	3.5
	1963	61	2.2	0.9	5.0
	1964	52	2.2	0.8	4.3
	1965	45	2.0	1.0	3.0

[a] Age given as of last birthday prior to death or surgery; ages greater than 24 years not included.
[b] Or surgical procedure.
[c] Mean values given in this table for the various years within each age group may not be directly comparable because of variations in sampling locations from year to year; however, the data are given as a summary of presently available results.

STRONTIUM-90 IN HUMAN VERTEBRAE 1965 RESULTS [1]

Health & Safety Laboratory
Atomic Energy Commission

One of the problems under investigation at the Health and Safety Laboratory (HASL) is the relation between diet levels of strontium–90 and bone strontium–90 concentrations. Since 1960, quarterly analyses of foods and estimates of the dietary intake of strontium–90 at New York City, Chicago, and San Francisco have been made at HASL (*1*). Measurements of the strontium–90 content of human bone from residents of these same cities have been made at HASL since 1960 (*2*). Results of the analyses of specimens obtained during 1965 are listed in tables 1 through 3. Average strontium–90/calcium ratios of children's vertebrae from New York City and San Francisco, with respect to age, are shown in figure 1.

It can readily be seen from figure 1 that the variation of strontium–90 concentrations in children's bones with age were similar in New York City and in San Francisco, although the New York City levels were higher. As in previous years, highest strontium–90 concentrations

[1] Material authored by Mr. J. Rivera, from Fallout Quarterly Summary Report, HASL–172, July 1, 1966. Available from the Clearinghouse for Federal Scientific and Technical Information, CFSTI, 5285 Port Royal Road, Springfield, Virginia 22151.

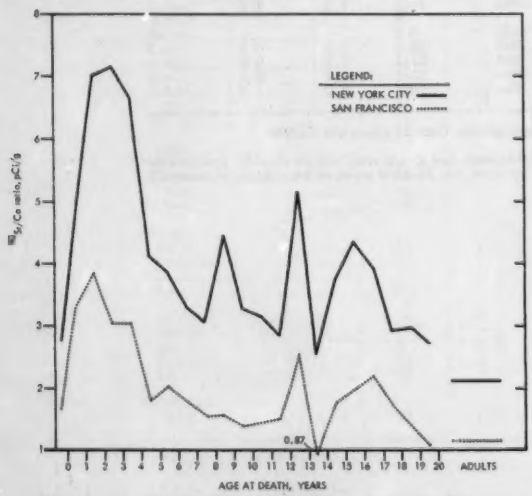

Figure 1. Strontium–90/calcium ratios in human vertebrae, 1965

Table 1. Strontium-90/calcium ratios in human vertebrae of New York City children, 1965

Age, years	Strontium-90/calcium ratios (pCi/g)	Number of specimens	Average (pCi/g)
<1 mo	* 2.79 (6)	6	2.79
1 mo–1 yr	4.97 (5)	5	4.97
1–2	7.02 (3)	3	7.02
2–3	7.17 (2)	2	7.17
3–4	9.10 6.82 6.00 (2) 6.01 (2)	6	6.66
4–5	4.26 3.97	2	4.12
5–6	3.39 3.95 4.17	3	3.84
6–7	4.86 1.72	2	3.29
7–8	3.05	1	3.05
8–9	4.44	1	4.44
9–10	3.57 2.28 3.87	3	3.24
10–11	2.87 3.20 2.96 3.61	4	3.16
11–12	3.37 1.23 3.93	3	2.84
12–13	5.17	1	5.17
13–14	2.51	1	2.51
14–15	3.76	1	3.76
15–16	3.71 4.03 5.36 4.27	4	4.34
16–17	3.36 4.45	2	3.91
17–18	2.33 3.55	2	2.94
18–19	2.71 1.82 3.44 3.89 2.92 3.12 3.03	7	2.99
19–20	3.66 2.57 1.89	3	2.71

* Parentheses indicate number of individual samples in the composite.

were found in the bones of young children and infants, lowest strontium–90 concentrations were found in the bones of adults, and there was some indication of an increase in strontium–90 concentrations in bone during early adolescence. On the average, strontium–90/calcium ratios in bones from children who lived in New York City were twice as high as those from children who lived in San Francisco prior to death. This finding is consistent with the observations of the Tri-City Diet studies which indicate that the daily intake of strontium–90 in New York City has consistently been about twice as high as the daily intake of strontium–90 in San Francisco.

The results of the analyses of vertebrae from adults are listed in table 3. As in previous years, and consistent with the results of the Tri-City Diet studies, highest strontium–90/calcium ratios were found in the specimens from New

Table 2. Strontium-90/calcium ratios in human vertebrae of San Francisco children, 1965

Age, years	Strontium-90/calcium ratios (pCi/g)	Number of specimens	Average (pCi/g)
<1 mo	[a] 1.38(4) 1.45(4) 1.61(6) 1.23(6) 2.37(6)	23	1.64
1 mo–1 yr	4.42 5.60 1.44 3.14(10)	13	3.30
1–2	3.50(2) 4.20(3) 3.33	6	3.82
2–3	3.07	1	3.07
3–4	1.01 4.82 3.22	3	3.02
4–5	1.60 1.81 2.07 1.89 1.80	5	1.83
5–6	0.55 2.57 3.01	3	2.04
6–7	—	—	—
7–8	1.53	1	1.53
8–9	1.54	1	1.54
9–10	1.40 2.33 0.45	3	1.39
10–11	—	—	—
11–12	0.48 2.51	2	1.50
12–13	2.56	1	2.56
13–14	0.87	1	0.87
14–15	1.79	1	1.79
15–16	—	—	—
16–17	2.20	1	2.20
17–18	1.78	1	1.78
18–19	—	—	—
19–20	0.71 0.89 1.62 1.09	4	1.09

[a] Parentheses indicate number of individual samples in the composite.

Table 3. Strontium-90/calcium ratios in human vertebrae of adults, 1965

City	Age range (years)	Strontium-90/calcium ratios (pCi/g)	Number of specimens	Average (pCi/g)
New York	20–30	1.69 1.87 1.81 2.98 1.70 1.33	6	1.90
	30–60	2.33 2.34 2.64 2.04 1.84 2.50	6	2.28
	>60	1.70 2.72 2.18 2.37	4	2.24
	>20	—	16	2.13
Chicago	20–30	1.11 2.85 1.84	3	1.93
	30–60	1.26 1.81 1.06 0.84 0.42 0.57 1.69 2.08 1.56 0.67 0.70 0.67 1.77	13	1.16
	>60	—	—	—
	>20	—	16	1.30
San Francisco	20–30	0.59 1.72 0.94 1.13	4	1.10
	30–60	1.22 1.31 0.93 2.14 1.04 0.71 0.74 0.38 1.19 0.96 0.66 1.46 1.42 0.45 0.60 0.74 1.93 1.28 1.21 2.54 2.24	21	1.20
	>60	0.39 1.11 0.68 1.57 1.49	5	1.05
	>20	—	30	1.16

York City, lowest values were found in bones from San Francisco, and intermediate values were found in bones from Chicago. As with children's bones, the strontium–90 concentrations of adult vertebrae from New York City residents were about twice as high as those from San Francisco residents.

It has been suggested that the concentrations of strontium–90 in human bone are described more correctly by a log-normal distribution, than by a normal distribution (*3*). A study is being made of the distribution of strontium–90/calcium ratios found in the relatively large and homogeneous groups of San Francisco adult samples. It appears at present that both distributions adequately describe the observed data; but further statistical analysis, now in progress, will be needed before it can be decided whether or not one distribution function describes the observed data significantly better than the other distribution.

In an earlier report (*2*), two formulas were given that could be used to predict the strontium–90/calcium ratios (X_n) of infant and adult bone, from information on the average diet strontium–90/calcium ratio (Z) during the year, and the average level of strontium–90/calcium in bone (X_{n-1}) at the beginning of the year. The formulas were:

for infants: $X_n = 0.2\ Z$

for adults: $X_n = 0.9\ X_{n-1} + 0.02\ Z$

These equations were used to predict the levels of strontium–90 in infant and adult bone during 1965. The predicted and observed values are shown in table 4.

Table 4. Predicted and observed strontium-90/calcium ratios in bone, 1965

City	Strontium-90/calcium, pCi/g					
	Infants			Adults		
	Z	X_n		X_{n-1}	X_n	
		Predicted	Observed		Predicted	Observed
New York City	24	4.8	5.0	2.0	2.0	2.1
Chicago	20	4.0	—	1.4	1.7	1.3
San Francisco	12	2.4	3.3	1.2	1.3	1.2

It appears that the formulas are reasonably valid for predicting strontium–90/calcium ratios in infant and adult bone. It should be noted, however, that the results of the analyses of bones from a single year cannot be used to unequivocally test the validity of a prediction model for strontium–90 levels in bone, because of the small number of bone samples usually available for analysis in 1 year, and the consequent uncertainty in the estimated mean strontium–90 levels for each age. An example of the influence of these uncertainties is seen in the results of the application of the equation for adults. Clearly the strontium–90/calcium levels in adult bone must increase so long as the level in bone is less than about one-fourth the strontium–90/calcium level in the diet. The observed average values for adult vertebrae for Chicago and San Francisco, however, were not higher in 1965 than in 1964. This, no doubt, must be due to the uncertainties in the estimates of the mean levels in 1964 and 1965.

The direct determination of the parameters governing strontium metabolism in children is difficult, if not impossible. From continuing measurements of the strontium–90 content of human bone and diets, it may be possible to make some quantitative inferences as to the variation of strontium metabolism with age. Data obtained during 1965 will be combined with previously obtained results to give new provisional estimates of the factors influencing this variation (*4*).

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ENVIRONMENTAL LEVELS OF RADIOACTIVITY AT ATOMIC ENERGY COMMISSION INSTALLATIONS

The U.S. Atomic Energy Commission receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual." [1]

Summaries of the environmental radioactivity data follow for the Brookhaven National Laboratory and the Rocky Flats Plant.

[1] Part 20, "Standards for Protection Against Radiation," AEC Rules and Regulations, contain essentially the standards published in the "AEC Manual." The AEC Rules and Regulations are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

1. Brookhaven National Laboratory January–June 1966 [2]

Associated Universities, Inc.
Upton, New York

The Brookhaven National Laboratory (BNL) operations may affect the environmental levels of radiation in three ways: (1) by discharge of coolant air from the graphite research reactor, (2) by radiation from an ecology forest gamma source, and (3) by the discharge of low-level radioactive liquid wastes into a small stream that forms one of the headwaters of the Peconic River (figure 1).

Area monitoring

The radioactivity in the discharge coolant air is almost entirely due to argon–41, a beta-gamma emitter. Because exposure to argon–41 is due to external gamma, the monitoring is performed by measuring the exposure rate in milliroentgens per week (mR/wk) rather than the concentration in air.

Late in 1961, a 10,000-curie cesium–137 gamma source was installed in the ecology forest about 800 meters equidistant from the north and east boundaries. The radiation levels resulting from the research reactor effluent and the ecology forest source are monitored continuously by four stations located along the site perimeter (figure 2).

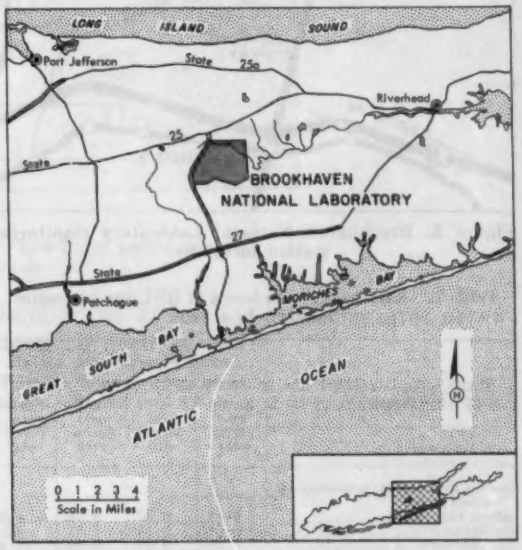

Figure 1. Brookhaven National Laboratory and surrounding area

Radiation levels at the northeast perimeter are somewhat greater than at other monitoring stations due to the ecology forest source. However, the radiation levels at this location are within the established AEC standard which is 0.5 rem/yr for individuals in the general population. The average weekly radiation levels at the Brookhaven National Laboratory site perimeter, due to laboratory operations, are given in

[2] Summarized from "Effects of Brookhaven National Laboratory on Environmental Levels of Radioactivity during the First Half of 1966," Associated Universities, Inc., Upton, New York.

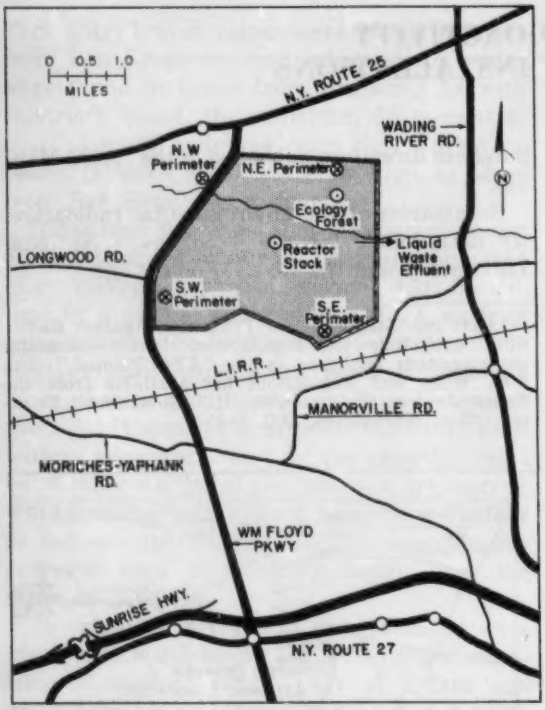

Figure 2. Brookhaven National Laboratory monitoring station locations

Table 1. External gamma levels at BNL site perimeter January–June 1966

Period	Average exposure rates, mR/wk			
	Northwest perimeter	Southwest perimeter	Southeast perimeter	Northeast perimeter
Gamma exposure from laboratory operations:				
First half 1966	0.18	0.20	0.46	2.32
January	0.04	0.18	1.07	1.56
February	0.16	0.04	0.40	1.80
March	0.26	0.09	0.25	1.95
April	0.09	0.08	0.29	1.92
May	0.31	0.43	0.54	2.60
June	0.18	0.39	0.28	3.80
Average undisturbed background	1.91	1.72	1.90	1.95

table 1. Values of radiation background levels undisturbed by laboratory operations have also been included in table 1 for purposes of comparison.

Water monitoring

The liquid waste effluent from the laboratory sewage processing plant is monitored continuously at the point where it is discharged to the small stream. The values of concentration and activity in the stream where it leaves the BNL site are computed on the basis of continuous measurements of the stream flow rate. The gross concentration and amount of radioactivity in the laboratory's liquid waste effluent, as it leaves the site, are shown in table 2.

Analysis of composite samples of the effluent has shown that, on the average, no more than 20 percent of the activity consists of strontium-90 and that no appreciable amounts of radioactive iodine or radium and other bone-seeking isotopes are present. The average gross concentration for the 6-month period, 38 picocuries per liter, was less than the established AEC standard for concentrations in effluents to unrestricted areas.

Table 2. Gross activity in BNL liquid waste effluent at site boundary, January–June 1966

Period	Average concentration (pCi/liter)	Total activity discharged, mCi
First half 1966	38	20.6
January	30	2.2
February	49	4.3
March	38	2.9
April	31	2.9
May	32	3.1
June	48	5.3

Previous coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December 1961	June 1962
January–June 1962	January 1963
July 1962–June 1963	February 1964
July 1963–June 1964	December 1964
July–December 1964	June 1965
January–June 1965	December 1965
July–December 1965	June 1966

2. Rocky Flats Plant January–June 1966 [3]

Dow Chemical Company
Golden, Colorado

The Rocky Flats Plant (RFP) is engaged in routine production operations involving plutonium and uranium under contract to the Atomic Energy Commission. Its location relative to population centers is shown in figure 3. To

[3] Summarized from "Environmental Survey, January–June 1966," Dow Chemical Company, Rocky Flats Division, Golden, Colorado.

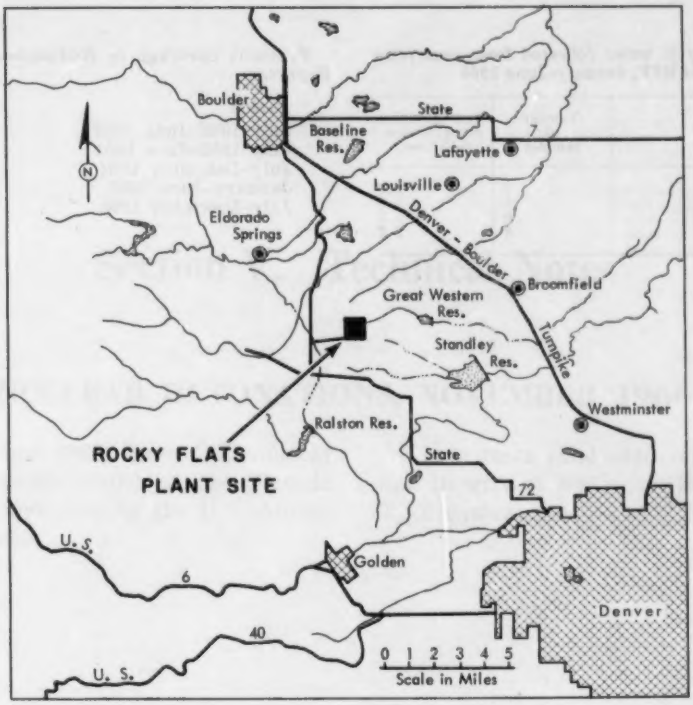

Figure 3. Location of the Rocky Flats Plant environment Denver, Colorado

assure properly controlled release of radioactive materials to the environment, periodic samples of water, air, and vegetation are analyzed for gross alpha activity. The most abundant radioactive material involved in the process is plutonium.

The plant is located about 15 miles northwest of Denver. The surface stratum in this area consists of gravel washed out of the highly mineralized Front Range of the Rocky Mountains, where heterogeneous low-level deposits of uranium, thorium, and radium exist in the soil. These materials are measurable in most samples of air, water, and vegetation.

Air

Continuous 24-hour air samples were collected at Coal Creek Canyon, Marshall, Boulder, Lafayette, Broomfield, Wagner School, Golden, Denver, and Westminster. The monthly average long-lived gross alpha activities shown in table 3 are believed to result from naturally occurring materials. All values are less than the AEC standard of 0.04 pCi/m^3 for mixtures of unidentified nuclides.

Table 3. Long-lived gross alpha activity in airborne particulates collected in the vicinity of RFP, January–June 1966

Period	Average alpha concentration (pCi/m^3)
January	0.006
February	<0.006
March	0.007
April	0.009
May	0.010
June	<0.006

Water

Regular water samples were obtained once every 2 weeks except during the winter months from 4 reservoirs in the area of the Rocky Flats Plant. The results of alpha activity analyses performed on these samples are given in table 4. The analytical results for water samples obtained during June from outlying streams and lakes and for the 1966 vegetation sampling program will be reported in a subsequent issue of *Radiological Health Data and Reports.*

Table 4. Alpha activity in water collected from reservoirs in the vicinity of RFP, January–June 1966

Reservoir	Number of samples	Average alpha concentration (pCi/liter)
Great Western	8	2.0
Standley	8	1.2
Baseline	8	1.7
Ralston	8	2.8

Previous coverage in *Radiological Health Data and Reports:*

Period	Issue
July 1962–June 1963	February 1964
July 1963–June 1964	December 1964
July–December 1964	June 1965
January–June 1965	December 1965
July–December 1965	June 1966

Section V. Technical Notes

REPORTED NUCLEAR DETONATIONS, NOVEMBER 1966

During November 1966, three U.S. nuclear tests conducted underground at the Nevada Test Site, were announced by the U.S. Atomic Energy Commission.

These tests conducted on November 5, 11, and 18 were of low yield (less than 20 kilotons TNT equivalent).

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SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished in reference card format for the convenience of readers who may wish to clip them for their files.

SUMMARY OF CESIUM–137 AND STRONTIUM–90 CONCENTRATIONS REPORTED IN CERTAIN ALASKAN POPULATIONS AND FOODSTUFFS, 1961–1966. *R. P. Chandler* and *D. R. Snavely. Radiological Health Data and Reports, Vol. 7, December 1966, pp. 691–696.*

Published data on cesium–137 and strontium–90 concentrations in certain Alaskan populations and foodstuffs are reviewed and summarized along with food consumption data. Where possible, concentrations in the diet and those found in people are compared to FRC guidelines. The seasonal and yearly trends of cesium–137 and strontium–90 concentrations in the diet of Alaskan populations and in people are discussed.

KEY WORDS: Alaska, body burdens, cesium–137, Eskimos, strontium–90.

CESIUM–137 BODY BURDENS IN ALASKAN MEN, SPRING 1966. *D. Fitzpatrick, J. L. Russell, O. G. Briscoe,* and *C. R. Calvert. Radiological Health Data and Reports, Vol. 7, December 1966, pp. 691–696.*

The cesium–137 body burdens of caribou-eating Alaskan men continue to be elevated, although in general the average body burdens are decreasing, compared to those observed in 1965. Elevated cesium–137 body burdens are well correlated with caribou (reindeer) consumption, and non-caribou eaters exhibit cesium–137 body burdens similar to residents in the conterminous United States. Of the 418 adult males counted during the spring of 1966, none was observed to have a cesium–137 body burden in excess of the guidance of the Federal Radiation Council (3,000 nCi), although one subject was found with a body burden of 80 percent (2,400 nCi) of this level.

KEY WORDS: Alaska, body burden, caribou, cesium–137, deposition, diet, fallout.

ERRATUM

A statement appearing in the data "Iodine–131 in Bovine Thyroids, July–December 1965" (Radiol Health Data Rep 7:601–604, October 1966) should be amended. The statement on page 601 beginning "The influx of fallout" should read "The continued influx of iodine–131 fallout following the mainland China atmospheric nuclear detonation of May 14, 1965, was observed to be generally low (<150 pCi/g thyroid) during July 1965, declining to barely detectable levels in late July 1965. Considerably higher values were seen in several of the individual thyroids collected during June 1965 (*2*)."

(*2*) PUBLIC HEALTH SERVICE, DIVISION OF RADIOLOGICAL HEALTH. Iodine–131 in bovine thyroids, January-June 1965. Radiol Health Data Rep 7:49–55 (January 1966).

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SYMBOLS, UNITS, AND EQUIVALENTS

Symbols	Units	Equivalents
BeV	billion electron volts	equals GeV
Ci	curie	3.7×10^{10} dps
cm	centimeter(s)	0.394 inch
cpm	counts per minute	
dpm	disintegrations per minute	
dps	disintegrations per second	
eV	electron volts	1.6×10^{-12} ergs
g	gram(s)	
GeV	giga electron volts	1.6×10^{-3} ergs
kg	kilogram(s)	1,000 g = 2.205 lb
km^2	square kilometer(s)	
kVp	kilovolt peak	
m^3	cubic meter(s)	
mA	milliampere(s)	
mCi/mi^2	millicuries per square mile	0.386 nCi per square meter (mCi/km^2)
MeV	million (mega) electron volts	1.6×10^{-6} ergs
mg	milligram(s)	
mi^2	square mile(s)	
ml	milliliter(s)	
mm	millimeter(s)	
nCi/m^2	nanocuries per square meter	2.59 mCi per square mile
pCi	picocurie(s)	10^{-12} curie = 2.22 dpm
R	roentgen	
rad	unit of absorbed radiation dose	100 ergs per gram

INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	tĕr' a
10^{9}	giga	G	jĭ' ga
10^{6}	mega	M	mĕg' a
10^{3}	kilo	k	kĭl' o
10^{2}	hecto	h	hĕk' to
10	deka	da	dĕk' a
10^{-1}	deci	d	dĕs' i
10^{-2}	centi	c	sĕn' ti
10^{-3}	milli	m	mĭl' i
10^{-6}	micro	μ	mi' kro
10^{-9}	nano	n	năn' o
10^{-12}	pico	p	pē' co
10^{-15}	femto	f	fĕm' to

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